Ocean Engineering 92 (2014) 234–244

Contents lists available at ScienceDirect

Ocean Engineering

journal homepage: www.elsevier.com/locate/oceaneng

On the stability of a free-to-rotate short-tail fairing and a splitter plate as suppressors of vortex-induced vibration

Gustavo R.S. Assi [a,*], Peter W. Bearman [b], Michael A. Tognarelli [c]

[a] *Dept. of Naval Arch. and Ocean Eng., University of São Paulo, São Paulo, Brazil*
[b] *Department of Aeronautics, Imperial College, London, UK*
[c] *BP America Production Company, Houston, USA*

ARTICLE INFO

Article history:
Received 10 December 2013
Accepted 20 October 2014
Available online 6 November 2014

Keywords:
Vortex-induced vibration
Galloping
Suppression
Splitter plate
Short-tail fairing
Offshore risers

ABSTRACT

Experiments in the Reynolds number range of 1000 to 12,000 have been carried out on a free-to-rotate short-tail fairing fitted to a rigid length of circular cylinder to investigate the effect of rotational friction on the stability of this type of VIV suppressor. Measurements of the dynamic response are presented for models with low mass and damping which are free to respond in the cross-flow and streamwise directions. It is shown how vortex-induced vibration can be reduced if the rotational friction between the cylinder and the short-tail fairing exceeds a critical limit. In this configuration the fairing finds a stable position deflected from the flow direction and a steady lift force appears towards the side to which the fairing has deflected. The fluid-dynamic mechanism is very similar to that observed for a free-to-rotate splitter plate of equivalent length. A non-rotating fairing as well as splitter plates is shown to develop severe galloping instabilities in 1-dof experiments.

1. Introduction

Efficient suppression of flow-induced vibration (FIV) of slender submarine structures is a challenging and interesting problem for the offshore industry and the scientific community. Various methods for suppressing vortex-induced vibrations (VIV) of bluff bodies have been investigated over the past decades. With the advancement of offshore oil exploration, research on VIV suppressors was pushed to a new level. The industry demands suppressors that are not only efficient for low mass-damping systems but also that could be installed under harsh environmental conditions; such is the case for offshore risers. Zdravkovich (1981) and Every et al. (1982) present comprehensive reviews of solutions varying from the simple attachment of ribbons to quite expensive devices such as helical strakes and fairings. Drilling risers may typically be inspected more often than production risers, therefore fatigue damage is not as important a concern as the steady loads caused by strong currents. Therefore, besides suppressing FIV, suppressors must reduce drag consequently reducing pipe bend and wear risk during drilling operations.

It is known that free-to-rotate suppressors may experience hydrodynamic instabilities that will not only cause a substantial increase in drag but also prevent them from suppressing vibrations (Assi et al., 2009). Actually, an unstable free-to-rotate suppressor may induce more vigorous structural vibrations excited by a type of flutter mechanism. Assi et al. (2009) have shown that the instability of free-to-rotate suppressors is directly related to the level of rotational resistance encountered in the system as well as geometric parameters such as plate length. They performed experiments in laboratory scale and showed that a free-to-rotate suppressor formed by a single splitter plate may need a minimum rotational resistance (or be above a critical rotational friction) to enable a stable configuration with effective suppression. The same was verified for free-to-rotate suppressors composed of two parallel plates (Assi et al., 2012), revealing that a minimum rotational resistance is necessary to stabilise the devices. Assi et al. (2009, 2010a) have also shown that 1D-long parallel plates can be very efficient in suppressing both VIV and WIV (wake-induced vibration). WIV occurs when the downstream body of a set is excited by the unsteady wake generated from another body placed upstream (Assi et al., 2010b, 2013a).

In the present work we contribute to the understanding of the hydrodynamic mechanism behind a type of free-to-rotate device known as the short-tail fairing compared with a cylinder associated with a simple geometry of a splitter plate. We focus on the dynamic stability and hydrodynamic phenomena that cause the

---

[*] Correspondence to: PNV Dept. Eng. Naval e Oceânica, Escola Politécnica da Universidade de São Paulo, Av. Prof Mello Moraes 2231, 05508-030 São Paulo – SP, Brazil.
E-mail address: g.assi@usp.br (G.R.S. Assi).
URL: http://www.ndf.poli.usp.br (G.R.S. Assi).

http://dx.doi.org/10.1016/j.oceaneng.2014.10.007

Nomenclature

$\overline{C}_x$	mean drag coefficient
D	cylinder external diameter
f_{0_x}	streamwise natural frequency measured in air
f_{0_y} or f_0	cross-flow natural frequency measured in air
f_x	streamwise oscillation frequency
f_y	cross-flow oscillation frequency
L/D	non-dimensional length of the splitter plate
m^*	mass ratio
Re	Reynolds number
St	Strouhal number
U	flow speed
U/Df_0	reduced velocity
$\hat{x}/D$	non-dimensional streamwise harmonic amplitude of vibration
$\hat{y}/D$	non-dimensional cross-flow harmonic amplitude of vibration
δ	stable angular position of a free-to-rotate suppressor
ρ	specific mass of water
τ_f	torque due to rotational friction
τ_f^*	non-dimensional torque due to rotational friction
ζ	structural damping ratio

fairing and the splitter plate to behave in quite the same way. A parametric investigation of the geometry of suppressors, in special the splitter plate, is not the concern of the present work. For that matter, the reader may refer to other works of the same authors (Assi et al., 2012, 2013b; Assi and Franco, 2013).

2. Free-to-rotate suppressors

It is known that if vortex shedding from a fixed cylinder is eliminated, say by the use of a long splitter plate (Cimbala and Garg, 1991), then drag is reduced. Hence conceptually an effective VIV suppression device should be able to reduce drag rather than increase it. This simple idea was the motivation for the development of suppressors such as splitter plates and fairings that act primarily by disrupting the vortex shedding mechanism on the near wake of bluff bodies by delaying the interaction between the separated shear layers.

Assi et al. (2009) have shown that suppression of cross-flow and in-line VIV of a circular cylinder, with resulting drag coefficients less than that for a fixed plain cylinder, has been achieved using two-dimensional control plates in low mass-damping systems. A free-to-rotate splitter plate was also found to suppress VIV but instead of remaining aligned with the flow on the centreline of the wake the plate adopted a stable but deflected position when it was released. VIV was suppressed, throughout the range of reduced velocity investigated, and drag reduced below that of a plain cylinder. Cimbala and Garg (1991) had also observed this bi-stable behaviour for a free-to-rotate cylinder fitted with a splitter plate.

Particle-image velocimetry (PIV) measurements performed by Assi et al. (2009) showed that on the side to which the plate deflected the separating shear layer from the cylinder appeared to attach to the tip of the plate and this had the effect of stabilising the near wake flow. Vortex shedding was visible downstream but this did not feed back to cause vibrations. An unwanted effect was that a steady transverse lift force developed on the cylinder towards the side to which the splitter plate deflected. This steady lift could be eliminated by using a pair of splitter plates arranged so that the shear layers that spring from both sides of the cylinder attach to the tips of the plates. The maximum suppression and drag reduction occurred with a pair of free-to-rotate parallel plates installed on the sides of the cylinder.

Assi et al. (2009) also found that the level of rotational friction between the free-to-rotate plate and the cylinder plays a fundamentally important role, needing to be "high enough to hold the device in a stable position, while still allowing them to realign if the flow direction changes. Devices with rotational friction below a critical value oscillate themselves as the cylinder vibrates, sometimes increasing the amplitude of cylinder oscillation higher than that for a plain cylinder". All devices with rotational friction above a critical value appeared to suppress VIV and reduce drag. However, if the rotational resistance was above a limiting threshold the suppressors could not rotate and an undesired galloping response was initiated.

In the present study we set out with the hypothesis that short-tail fairings and short splitter plates are able to suppress VIV based on the same fluid-dynamic mechanism. Short-tail fairings are not "fairings" in the strict sense of the term, meaning that they do not make a streamlined body. For this to happen the length of the fairing would have to be many times the diameter of the cylinder, as shown in Henderson (1978), Wingham (1983) and Packwood (1990). In essence, we believe a short-tail fairing acts in the near wake with fully separated flow avoiding the interaction between the shear layers and delaying vortex shedding, therefore the same mechanism as the splitter plate.

If this is true, we expect short fairings to find stable but deflected positions towards one of the sides of the cylinder instead of aligning itself with the flow. In the same manner as splitter plates, the stability of short fairings might also depend on a minimum level of rotational friction in order to suppress VIV. The effect of rotational friction on the stability of a short-tail fairing is what this present study sets out to investigate. However, if friction is too high the suppressor may not find itself free to rotate around the cylinder, but stuck with no angular movement. If this is the case, the system becomes susceptible to galloping, which may cause severe vibrations in a very different fashion from VIV.

3. Experimental arrangement

Two types of suppressors were tested in this experimental campaign: a free-to-rotate splitter plate and a short-tail fairing. Fig. 1(a) presents the geometric parameters for the splitter plate. Plate length L/D could be varied by changing the plate made out of acrylic plastic. The short-tail fairing was made of a triangular

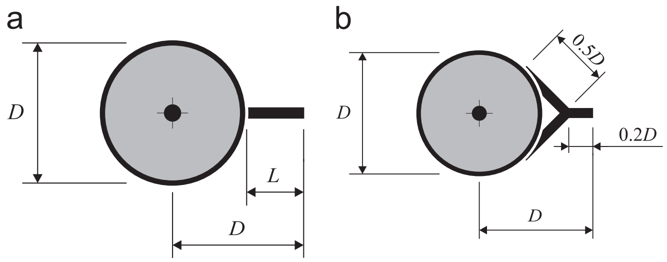

Fig. 1. Geometries for splitter plates and a short-tailed fairing. (a) Short splitter plate; (b) Short-tail fairing.