

Force and Correlation Length in Cables in Steady Flow

M.S. Triantafyllou
Massachusetts Institute of Technology (MIT), Room 5-323
Cambridge, MA 02139
phone: (617) 253-4335 fax: (617) 258-9389 e-mail: mistetri@mit.edu
Grant #: N00014-95-1-1106
<http://web.mit.edu/towtank/www>

LONG TERM GOALS

To obtain understanding of the basic flow-structure interaction mechanisms of marine cables subject to shear currents, so as to develop better predictive tools.

OBJECTIVES

- To map the flow behind vibrating flexible bluff bodies, using quantitative whole-field visualization, and a closed-loop force feedback apparatus, allowing the simulation of systems with complex structural impedance.
- To derive predictive models based on sectional force and flow measurements and correlation length studies.
- To corroborate the predictive models against experimental measurements on long flexible tethers.

APPROACH

We use a combined experimental/computational/theoretical approach. For experiments we use the Testing Tank Facility consisting of a larger tank (100 ft by 8 ft by 4 ft), and a smaller tank (8 ft by 2 ft by 1 ft). It is equipped with Digital Particle Image Velocimetry (DPIV) capability, allowing quantitative wake mapping, while we have constructed extensive apparatus for measuring forces on cylinders.

The Virtual Cable Testing Apparatus (VCTA), which has been developed, installed and tested extensively in the Testing Tank Facility, allows testing of cylinders in virtual free-vibration conditions (Hover, Techet & Triantafyllou 1997 and Hover, Miller & Triantafyllou 1997). It can be used to simulate conditions of complex modeled structural response coupled with real-time, experimentally measured wake dynamics. A hybrid system can be simulated, employing a closed-loop control system, which will consist of: (a) a pair of force transducers measuring the transverse forces at both ends of a cylindrical test section moving forward at constant speed; (b) a dedicated computer which uses in real-time the measured force to drive a numerical simulation of an equivalent system of desired structure; and (c) two servomotors and linear tables which impose, also in real-time, the numerically calculated motion to the cylinder section.

The apparatus results in an effective system with arbitrary structure. It has been used to simulate a mass-dashpot-spring system vibrating freely with very low effective damping (Hover, Techet & Triantafyllou 1998), as well as complex systems with several natural frequencies, including mode-coalescence conditions (Hover, Miller & Triantafyllou 1997).

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE 1998		2. REPORT TYPE		3. DATES COVERED 00-00-1998 to 00-00-1998	
4. TITLE AND SUBTITLE Force and Correlation Length in Cables in Steady Flow				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Massachusetts Institute of Technology, Cambridge, MA, 02139				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES See also ADM002252.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 4	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

WORK COMPLETED

We have mapped the dependence of the formation of hybrid modes behind long bluff cylinders, as identified in Techet et al (1998) and shown in Figure 1, on the effective shear in the flow. We have conducted visualization tests behind freely vibrating cylinders showing the effect of hybrid modes on the correlation length and the measured sectional forces.

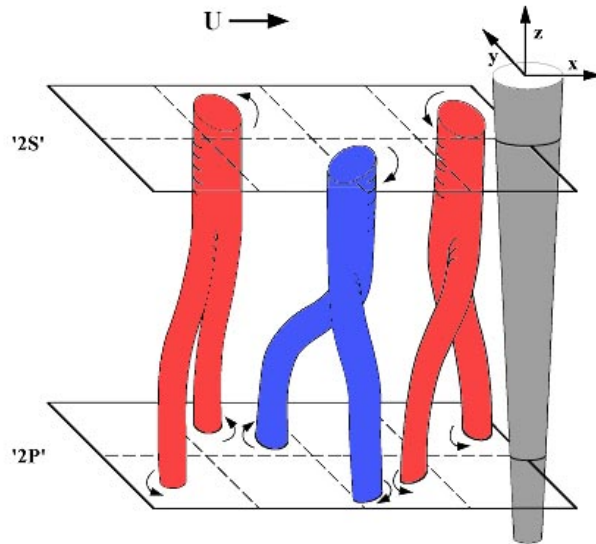


Figure 1. Sketch shows the proposed hybrid shedding mode behind a tapered oscillating cylinder with uniform free stream flow.

RESULTS

Within a narrow regime of reduced velocity containing the value $V_r=5$, forces measured at the two ends of a rigid vibrating cylinder appear to become uncorrelated. This is a surprising result since the cylinder still oscillates at high amplitude. We have shown conclusively since the last report that the apparent lack of correlation is due to the appearance of a hybrid mode, consisting of the stable coexistence of a “2-P” mode (two vortex pairs per cycle) over part of the length and “2-S” mode (two vortices per cycle) over the remaining length, connected through a vortex split. For short sections this change in mode along the length of the cylinder causes both a drop in excitation force and in hydrodynamic damping; hence, for low structural damping, high-amplitude vibrations are still possible since they depend on the ratio of the two quantities. For longer cylinders, such splits have a far more complex effect, requiring careful modeling.

IMPACT/APPLICATIONS

The identified mechanisms affecting correlation length provided needed understanding in order to properly model the flow behind vibrating bodies.

TRANSITIONS

Results from this study have been applied in the development of predictive codes for vibrating beams and cables in water.

RELATED PROJECTS

We have a working relation with related work led by Prof. Karniadakis of Brown University, and Dr. Mark Grosenbaugh of Woods Hole Oceanographic Institution. There is close cooperation with the "Free Surface Signatures of Submerged Objects" project led by Professors D. Yue and M. Triantafyllou.

PUBLICATIONS

Hover, F.S., Miller, S.N. & Triantafyllou, M.S., 1997: "Vortex-induced oscillations in inclined cables", *Journal of Wind Engineering and Industrial Aerodynamics*, 69-71, pp. 203-211.

Hover, F.S., Miller, S.N., Triantafyllou, M.S., 1997: "Vortex-induced vibration of marine cables: Experiments using force feedback", *Journal of Fluids and Structures*, 11, pp. 307-326.

Triantafyllou, M.S., 1998: "Cable Dynamics for Offshore Applications", *Handbook of Ocean Engineering*, Volume 4, Gulf Publishing Company, December 1998.

Techet, A.H., Hover, F.S. & Triantafyllou, M.S., 1998: "Vortical patterns behind tapered cylinders oscillating transversely to a uniform flow", *Journal of Fluid Mechanics*, 363, 79-96.

Hover, F.S., Techet, A.H. & Triantafyllou, M.S., 1998: "Forces on oscillating uniform and tapered cylinders in cross flow", *Journal of Fluid Mechanics*, 363, 97-114.

Tjavaras, A.A., Zhu, Q., Liu, Y., Triantafyllou, M.S. & Yue, D.K.P., 1998: "The mechanics of highly-extensible cables", *Journal of Sound and Vibration*, 213, 709-737.

Zhu, Q., Liu, Y., Tjavaras, A.A., Triantafyllou, M.S. & Yue, D.K.P., 1998: "Mechanics of nonlinear short-wave generation by a moored near-surface buoy", *Journal of Fluid Mechanics*, (to appear).

Triantafyllou, M.S., 1999: "Hydrodynamics of Fish Swimming", *Annual Review of Fluid Mechanics*, 32, (invited article).

Hover, F.S. & Triantafyllou, M.S., 1998: "The lock-in phenomena for cylinders with nonlinear compliance", Proceedings of the 1998 ASME Fluids Engineering Division Summer Meeting, 21-23 June, Washington, DC.

Hover, F.S. & Triantafyllou, M.S., 1998: "Some robotic applications in fluid mechanics: Vortex induced vibrations and fish propulsion", Proceedings of the 1998 ASME Fluids Engineering Division Summer Meeting, 21-23 June, Washington, DC.

Techet, A.H. & Triantafyllou, M.S., 1998: "The evolution of a 'hybrid' shedding mode", Proceedings of the 1998 ASME Fluids Engineering Division Summer Meeting, 21-23 June, Washington, DC.

Hover, F.S., Triantafyllou, M.S., 1997: “Structural mass and damping effects on forcing of compliantly-mounted cylinders in cross flow”, 50th Annual Meeting of the Division of Fluid Dynamics, American Physical Society, San Francisco, CA, November 23-25, 1997.

Techet, A.H., Triantafyllou, M.S., “Vortical patterns behind tapered cylinders oscillating transversely to a uniform flow”, 50th Annual Meeting of the Division of Fluid Dynamics, American Physical Society, San Francisco, CA, November 23-25, 1997.

Triantafyllou, M.S., 1998: “Robotic Applications in Experimental Fluid Mechanics”, Invited Seminar, Princeton University, March 1998.