Flow Visualization of Three Dimensional Effects in a Cylinder Wake Flow

An investigation into the effects of flow-normal translation on 3D structures in a circular cylinder wake

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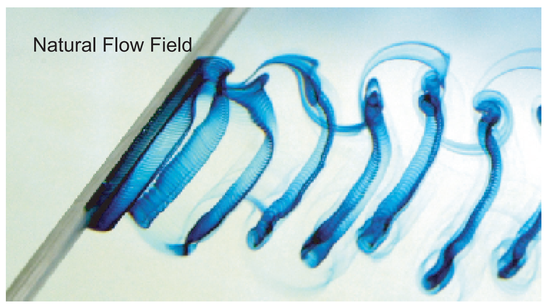
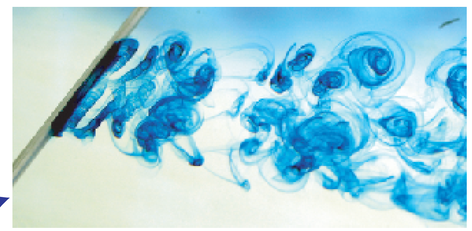
Re = 160



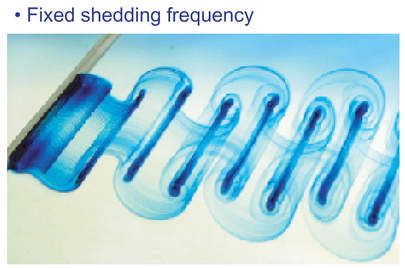
• Long Wavelength Spanwise phase variation; the phase distribution varies slowly with over time and is random
• No streamwise vortices
• Relatively constant shedding frequency

No Lock-In



• Forcing with f/f_N = 1.2; A/D = 0.25
• Long wavelength spanwise phase variation
• No streamwise vortices
• Shedding Frequency not constant
=> Chaotic flow behavior

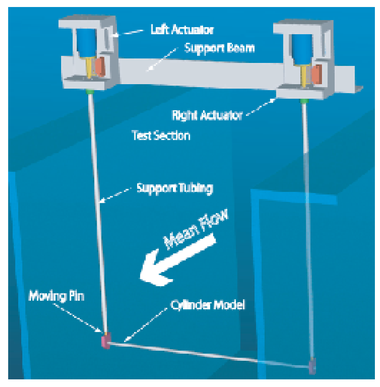
Lock-In



• Forcing with f/f_N = 0.8; A/D = 0.25
• Uniform spanwise phase
• No streamwise vortices
• Fixed shedding frequency

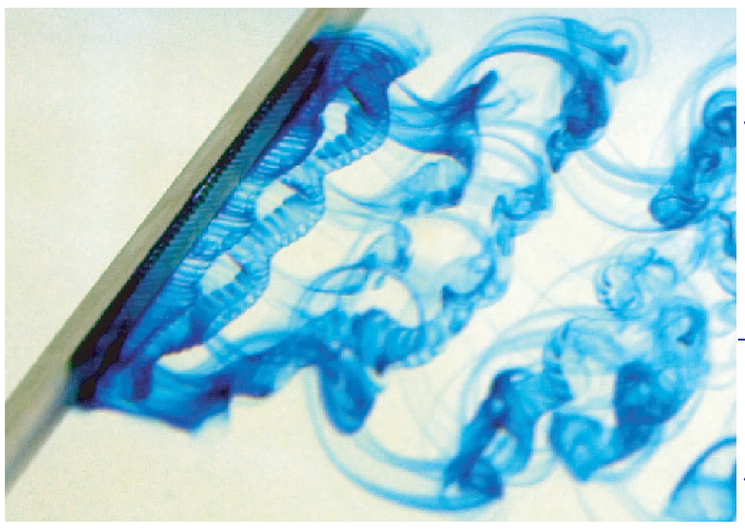
Experimental Setup

All Experiments were conducted in an Eidetics Model 1520 Water Tunnel. Blue dye was introduced into the wake through two rows of 0.6mm holes drilled in lines at angles of +-45 degrees from the freestream direction

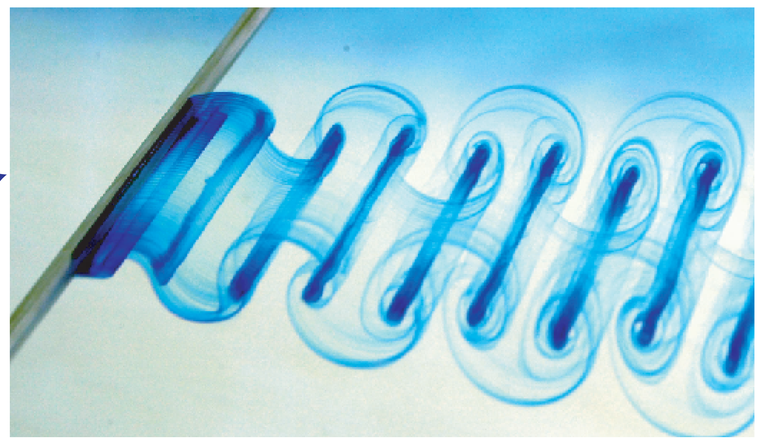


- **Cylinder Model: D = 3.97 mm**
- **Span: L = 381 mm => L/D ~ 95**
- **Natural Shedding frequency f_N = 1.22 Hz at Re=100**
- **Vertical Travel A: ± 4 mm pk max.**
- **Maximum forcing frequency f: >50Hz**

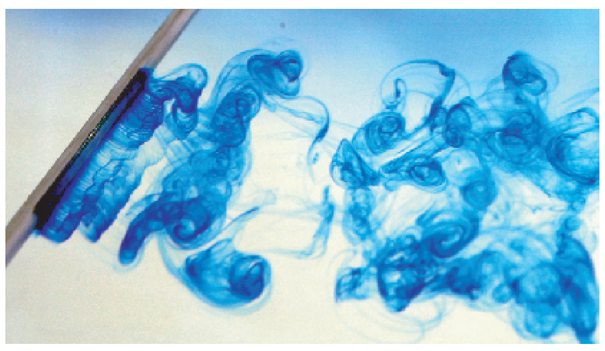
Re = 200



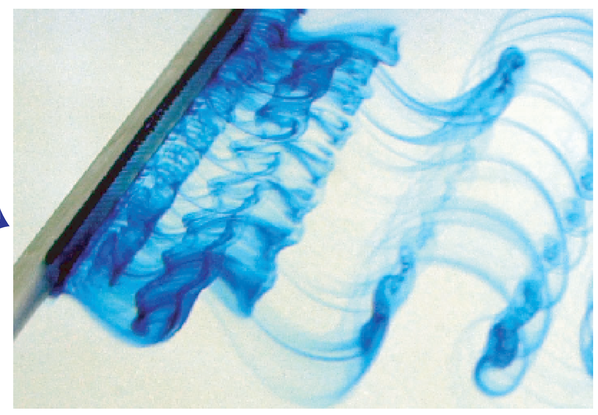
• Long Wavelength Spanwise phase variation
• Streamwise vortices of Type A, wavelength 3-4*D
• Relatively constant Karman vortex shedding frequency



• Forcing with f/f_N = 0.8; A/D = 0.25
• No spanwise phase variation
• Streamwise vortices of Type A are suppressed as well !
• Fixed Karman vortex shedding frequency

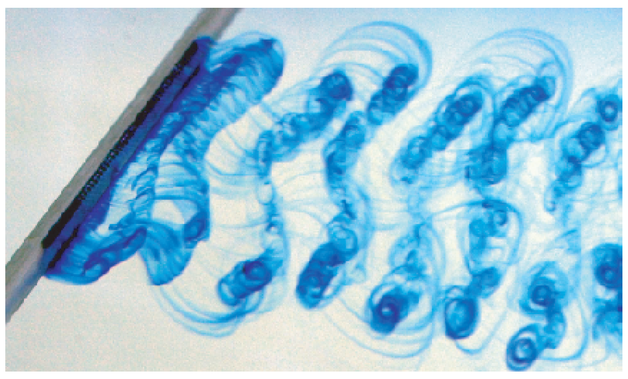


• Forcing with f/f_N = 1.2; A/D = 0.25
• Spanwise phase variation
• Streamwise vortices of Type A are present
• Karman vortex shedding frequency irregular, chaotic

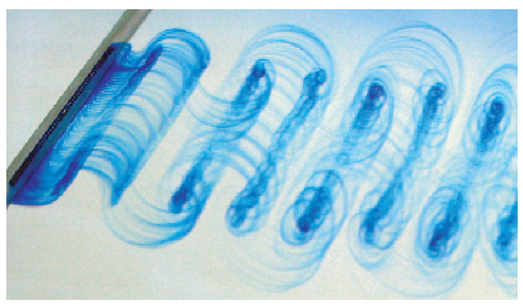


• Forcing with f/f_N = 0.7; A/D = 0.25
• Spanwise phase variation is suppressed
• Streamwise vortices of Type A are still present
• Fixed Karman vortex shedding frequency

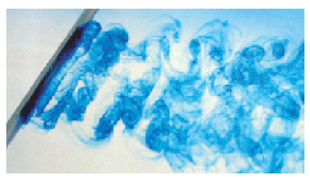
Re = 260



• Long wavelength spanwise phase variation
• Streamwise vortices of Type B, wavelength O~D
• Relatively constant Karman vortex shedding frequency



• Forcing with f/f_N = 0.8; A/D = 0.25
• Spanwise phase variation is suppressed
• Streamwise vortices of Type B are still present
• Fixed Karman vortex shedding frequency

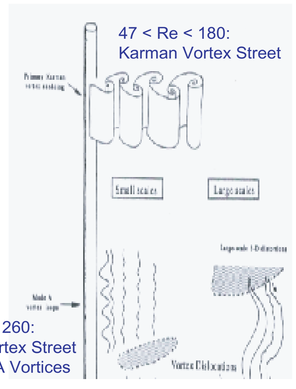


• Forcing with f/f_N = 1.1; A/D = 0.25
• Spanwise phase variation
• Streamwise vortices of Type B are present
• Karman vortex shedding frequency irregular, chaotic

Conclusions

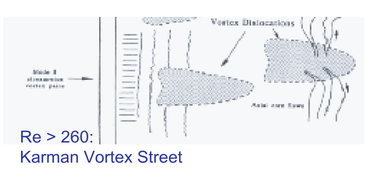
- **Forcing at Reynolds numbers where 3D structures are present can restore the flow to entirely 2D behavior.**
- **Forcing can achieve both spanwise coherence and fix the frequency of the Karman vortex street (lock-in) at Reynolds numbers above the onset of 3D instabilities**
- **At the borderline of lock-in, 3D mode A and B vortices may exist despite spanwise coherence and lock-in of the Karman vortex street.**

Background



180 < Re < 260:
Karman Vortex Street
and Mode A Vortices

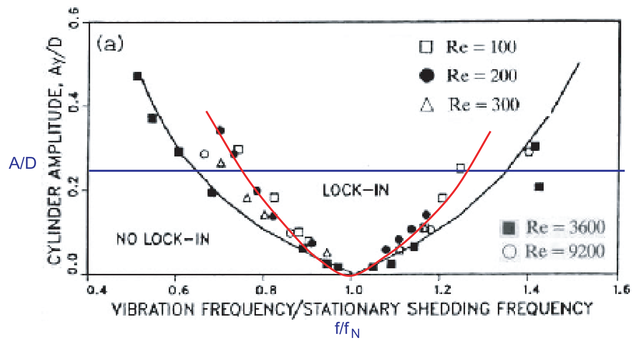
Unforced Cylinder Wake



Re > 260:
Karman Vortex Street
and Mode B Vortices

Source:C.H.K. Williamson, "Vortex Dynamics in the Circular Cylinder Wake", Ann. Rev. Fluid Mech. 1996, 28:477-539

Lock-In due to Periodic Translation



Source: Robert Blevins, 1990,"Flow-Induced Vibration", 2nd Edition, Van Nostrand Reinhold, pp 55.