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VORTEX INDUCED VIBRATIONS AT HIGH REYNOLDS NUMBERS

Giorgio Diana***, Marco Belloli*****, Stefano Giappino*****, Sara Muggiasca***

*Politecnico di Milano, Dipartimento di Meccanica
Campus Bovisa, Via La Masa 34, 20156 Milano, Italy
e-mails: `giorgio.diana@polimi.it`, `marco.belloli@polimi.it`,
`stefano.giappino@polimi.it`, `sara.muggiasca@polimi.it`

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1 INTRODUCTION

Vortex induced vibrations of circular section structures are a well known and deeply studied phenomenon and they can occur in many engineering applications. Many researchers deal with this topic and a general review can be found for instance in [6, 7]. The driven parameters of the fluid-elastic interaction can be attributed to the considered structure (dimensions, mass, damping ratio, natural frequency, surface roughness) and to the fluid (velocity, density, viscosity, turbulence intensity). In spite of this wide set of physical quantities a reduced set of non-dimensional parameters are the key variables that control the free motion response, i.e Scruton Number, mass-ratio and velocity-ratio. Moreover the wake topology is defined only by the velocity-ratio and the non-dimensional amplitude as described by Williamson & Roshko in [8]. Nevertheless up to now most part of the experimental results belong to a Reynolds Number range between 500 and $6 \cdot 10^4$ and no reliable numerical simulations are available for Reynolds higher than 3000 [6]. The vortex shedding on still circular cylinder depends on the Reynolds Number and it is well defined in the subcritical Reynolds range while it reduce its magnitude and sometimes disappears in the critical one [10]. Roshko, in 1961, found that the vortex shedding reappears at higher Reynolds Number in what is now called postcritical flow regime [4]. So there is the need to understand if and how the Reynolds Number affects also the vortex induced oscillations; in the paper experimental tests on a large diameter cylinder investigate the vortex induced dynamics at high Reynolds Numbers.

2 MODEL AN EXPERIMENTAL SET-UP

Experimental tests were carried out in air at the Politecnico di Milano wind tunnel. The model is a circular section cylinder in carbon fiber having the diameter of $0.72\,m$; it is suspended to the wind tunnel walls by means of tensioned wires realizing a constrain system that allows cross-wind oscillations as visible in Figure 1 and it has two end-plates in order to realize 2D flow conditions. The structural damping is adjusted by adding dampers to the system so that it is possible to vary the Scruton Number. The cylinder has several pressure taps arranged in

different rings connected to high sample-rate pressure scanners that allows the measurement of the aerodynamic force in terms of mean and fluctuating value. Accelerometers are placed on the model to evaluate the displacement in vertical direction.
In order to increase the effective Reynolds Number the model surface roughness is increased adding a nylon-net. A preliminary campaign on still cylinder was carried out to check the blockage effects and to measure the drag coefficient and the Strouhal Number to state that postcritical flow conditions are reached as described in [1]. As well known in fact, surface roughness addiction shifts the drag crisis to a lower Reynolds Number, permitting to reach high effective *Re* without increasing wind velocity.


(a) (b)

Figure 1: Cylinder model suspended by cables (a) with added surface roughness (b)

3 TEST RESULTS

Two different kind of tests were performed: progressive regimes and build-up. During progressive regime tests, steady state model response has been studied for different incoming flow velocity: each regime condition was reached starting from the previous one increasing or decreasing the wind speed. Figure 2 shows the main results of these tests: in Figure 2a there is the normalized oscillation amplitude obtained increasing (Up) and decreasing (Down) the incoming wind speed. The maximum displacement $z/D = 0.22$ was controlled by an high value of the Scruton Number ($Sc \approx 2$). It was not possible to reach larger amplitudes to avoid large stresses on the constrain structure. Figure 2b and Figure 2d describe the characteristics of the fluctuating lift force in terms of magnitude and relative phase with respect to the displacement. It is possible to note two different behaviors: for $V/V_{St} < 1$ the high value of the lift force is related with small phase value, while for $V/V_{St} > 1$ the lift force reduces its magnitude but the phase is very effective, close to $90\,deg$. This behavior is the same as described in literature by Khalak and Williamson for the response branches initial and lower [3]. Moreover it is visible an hysteresis due to the increasing or decreasing wind speed.

An example of build-up test is visible in Figure 3 that shows the lift force, the oscillation amplitude and the relative phase during the build-up transient. The velocity ratio $V/V_St = 0.98$ corresponds to initial branch in progressive regime tests. It is possible to see the variation of the aerodynamic force during the transient, in particular the lift force and the oscillation amplitude grow almost simultaneously and the phase shifts from values of about $90\,deg$ to values close to $0\,deg$. Build-up tests are very helpful because they permit to define the characteristics of the aerodynamic forces for all the combinations of z/D and V/V_{St} where the cylinder experience free motion.

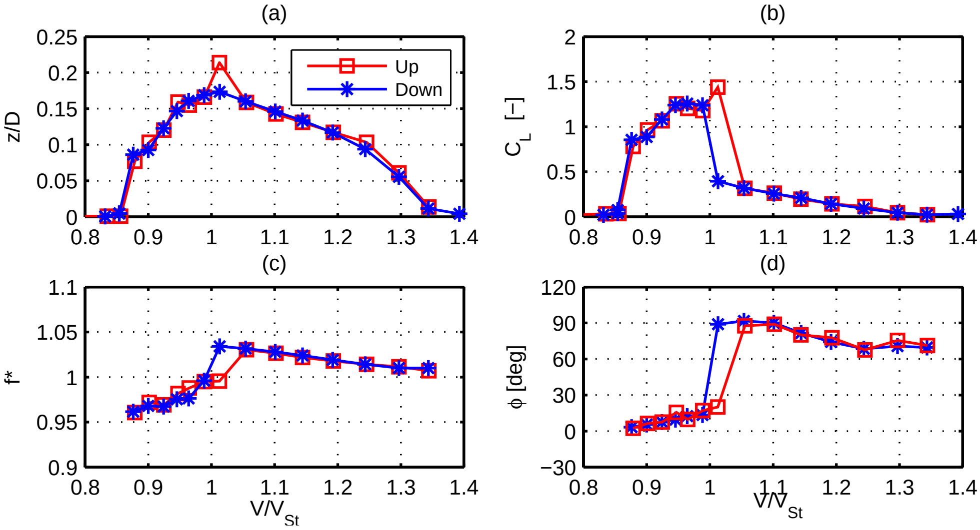

Figure 2: Progressive regime test results: non-dimensional amplitude as a function of the normalized velocity V/V_{St} (a), lift force magnitude and phase (b and d), frequency ratio (c). The data are obtained by increasing the wind velocity "Up" and decreasing "Down"

The test set-up allows the simultaneous measurement of the aerodynamic force and displacement of the body giving the possibility to define the power input by the flow into the mechanical system. Figure 4 reports the envelope of the maximum power input compared with previous data in subcritical Reynolds Number flow regime [2, 9].

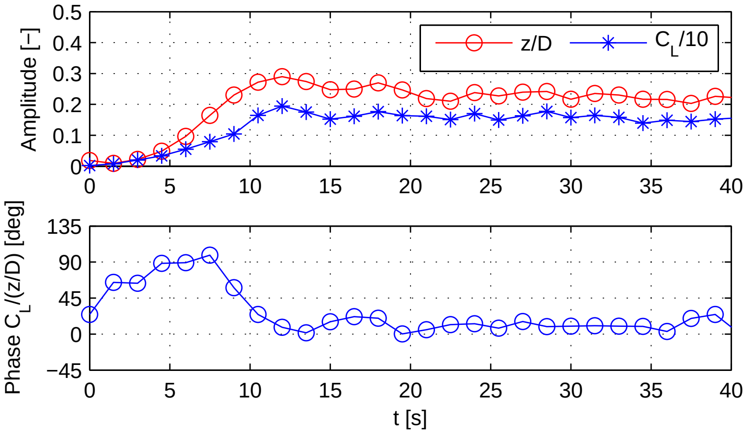

Figure 3: Build-up test results: non-dimensional amplitude and lift magnitude -divided by 10- (a) and phase between lift force and displacement (b). Data at $V/V_{St} = 0.98$

4 CONCLUSIONS

The described wind tunnel tests on a large diameter cylinder allowed the authors to investigate vortex induced vibrations at high Reynolds Number. In particular increasing the surface roughness it has been possible to simulate postcritical flow conditions. The results show the same response branches that are deeply described in literature for low Reynolds Number flows, highlighting that vortex induced phenomena are very similar in the different Reynolds conditions. In particular the specific power input curve shows good agreement among the different

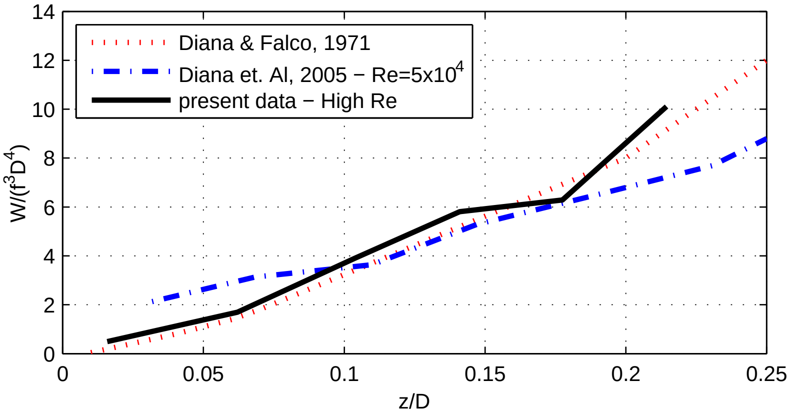

Figure 4: Power introduced by the flow on the oscillating cylinder: comparison of the present experimental data at postcritical Reynolds Numbers with previous ones in subcritical flow regime

Re. This latter fact is very important because numerical models used at low Reynolds could be adopted also in postcritical flow conditions.

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