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UNSTEADY AERODYNAMIC FORCES ON SQUARE CYLINDERS WITH SHARP AND ROUNDED CORNERS

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1 INTRODUCTION

In recent field observations, square lighting poles with rounded corners underwent higher oscillation amplitudes than previously installed square poles with sharp corners. This notion can be related to the structural properties of the different poles as well as to the difference in the unsteady components of the aerodynamic loads. As such, determining both static and dynamic loads on these bodies is important in order to characterize, predict and control their vortex-induced vibrations. The objective of this work is to quantify differences in the unsteady aerodynamic loads on cylinders with sharp and rounded corners. Such a quantification would enable the development of a reduced order model for these loads which can be used to predict and control associated vortex-induced vibrations.

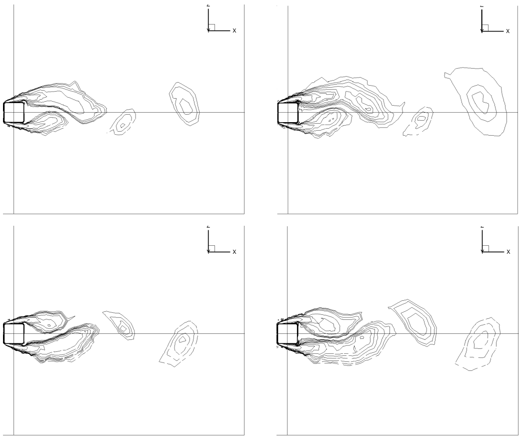

Figure 1: Isolines of Y vorticity component for four different time instants: top left and bottom left are plots relative to minimum and maximum lift time instants, respectively. Right plots represent instants when lift is approximatively null.

2 NUMERICAL SIMULATIONS

A series of three-dimensional numerical simulations of the flow past sharp and rounded corners cylinders at $Re = 22000$ has been conducted to characterize the aerodynamic loads in both time and frequency domains. The incompressible RANS equations with a $k - \omega$ closure model are solved using finite volume discretization. This has been implemented using the commercial software Fluent. In the full paper we will present a validation of these simulations with experimental measurements.

3 RESULTS

An example of time variations of the flow field around the rounded corner cylinder is presented in Fig. 1, displaying iso-lines of the vorticity component parallel to the cylinder's axis, for four different instants in a period of the vortex shedding. The plots clearly show the vorticity generation at the separation points over the cylinder and the vortices forming in its wake. As shown in the top images, the vorticity generated at the bottom side of the cylinder moves up and cuts the upper vorticity to yield vortex shedding of the upper vortex. This phenomenon is reversed and repeated as shown in bottom left and bottom right images, respectively. This reverse in the shedding of vorticity yields time variations in the surface pressures over the cylinder and is the cause for the periodic variations in the lift and drag coefficients.

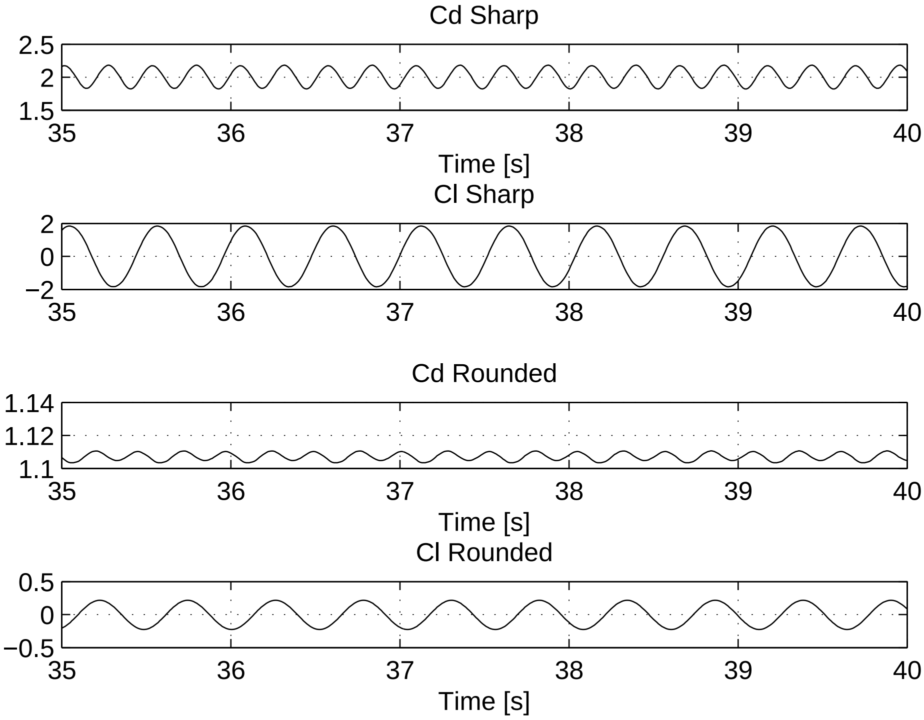

Figure 2: Time histories of lift and drag coefficients for both square and rounded corners cylinders, at $Re = 22000$. The C_D time histories represent the fluctuation around the mean values, namely $\overline{C}_{DR} = 1.11$ and $\overline{C}_{DS} = 2.01$ for the rounded and square corner cylinders respectively

The lift and drag coefficients were determined by integrating the pressure over the cylinders surfaces. Fig. 2 shows parts of the time histories of C_L and C_D coefficients. Mean and

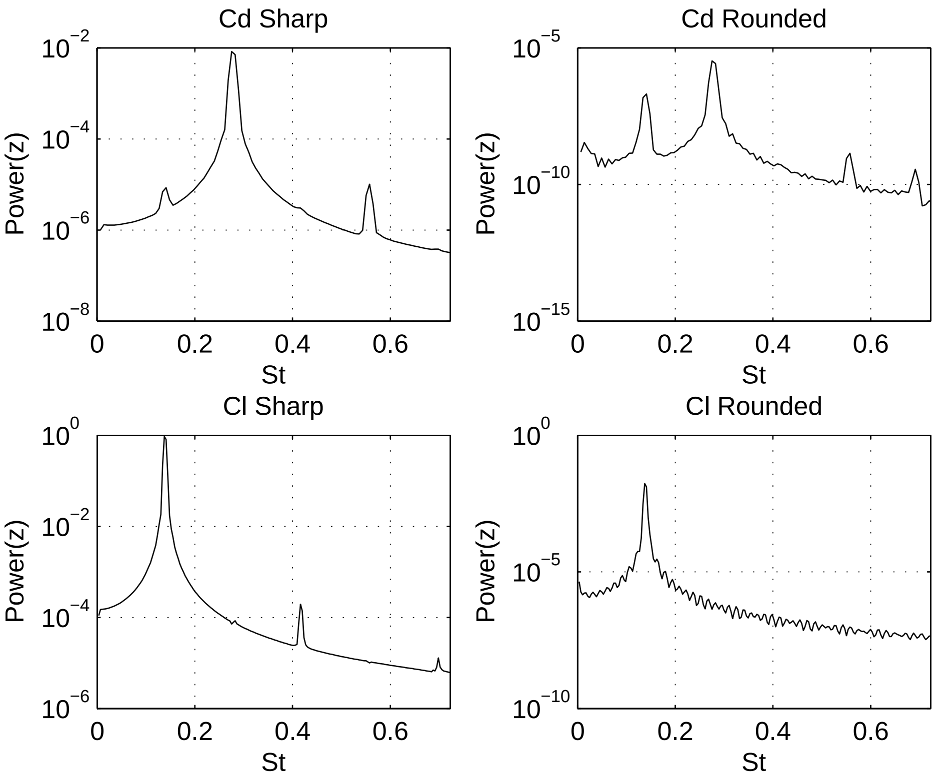

Figure 3: Power spectra for lift and drag coefficient time histories of both square and rounded corners cylinders, at $Re = 22000$

RMS values for the sharp corner aerodynamic coefficients are within the experimental and numerical values presented by Rodi [1] and obtained from different experiments and numerical simulations. The plots show that the amplitudes of oscillations for both C_L and C_D are significantly lower for the rounded corner cylinders. The lift coefficient amplitude on the cylinder with rounded corners is reduced by a factor of seven in comparison with that of the cylinder with sharp corners. The mean $\overline{C}_D$ value for rounded corner cylinders is approximately half of the corresponding coefficient for the cylinder with sharp corners. This is in agreement with the experimental results of Tamura et al.[2]. Moreover, the oscillation amplitudes of the drag coefficient for rounded corner cylinders are about 40 times lower than those computed for the cylinder with sharp corners.

The dynamic characteristics of the lift and drag oscillations are obtained from the lift and drag spectra which are presented in Fig. 3. The results show that the Strouhal number in both cases is near 0.137 as determined from the principal harmonic of the C_L coefficient. In the case of the square cylinder with sharp corners, the drag coefficient has one major harmonic at twice the frequency of the vortex shedding. This is different from the case of rounded corners where the drag coefficient has two major components at the vortex shedding frequency and its second harmonic. This difference would certainly have an implication on the aerodynamic forcing of square cylinders and their responses.

4 CONCLUSIONS

In this work, differences in the unsteady aerodynamic loads on cylinders with sharp and rounded corners are quantified. Differences in mean and RMS amplitudes for both coefficients are presented. Time and spectral analysis show a major difference in the frequency content of the drag coefficients of the two cases.

REFERENCES

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