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From squared with sharp corners up to circular:

Review of experimental results on the influence of the cross-sectional shape of smooth and rough 2D cylinders in cross-flow at high Reynolds numbers

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In the aerospace industry, the civil engineering and for marine applications a wide range of constructions can be found that mainly consist of cylindrical elements having cross-sectional shapes ranging from circular to square or rectangular with either sharp, rounded or chamfered edges or corners. A rounding of the edges has a positive effect on the reduction in the drag force and the fluctuations of the lift force, but at the same time introduces a higher vortex shedding frequency. Depending on the amount of roundness the behaviour of the flow around a cylindrical construction with a square cross section tends more to that known from a circular cylinder, hence an absence of fixed boundary layer transition and separation points and thus a strong dependency of the aerodynamic forces on the Reynolds number. The latter is in particular challenging for numerical simulations during the design stage. In case of floating offshore constructions, e.g. semi-submersible drilling rigs, spars or floating wind turbines, not only the cross-sectional shapes of the submerged parts of the structure and the direction and strength of the current and waves must be taken into account, but also the continuously increasing surface roughness due to marine growth and rust. Each one of these parameters has a large impact on the amount of susceptibility of these structures to vortex-induced vibrations, hence undesired harmonic low-frequency, high-amplitude motions. Typical Reynolds numbers lie here in the range of 10^6 to 10^8, for which to date hardly any literature on numerical, theoretical and experimental studies is available, in particular on the effect of surface roughness on the unsteady aerodynamics of single or multiple cylindrical elements having non-circular cross sections in cross-flow.

In the last few years several experimental studies have been performed in the High-Pressure Wind Tunnel Gottingen (DNW-HDG) to investigate the unsteady aerodynamics of smooth and slightly rough stationary cylinders with circular or rounded square cross sections, the latter having non-dimensional rounded corners of either r/D = 0.16 or 0.29, up to Reynolds numbers of 10 million. As a follow-up on these wind tunnel tests, the current study focuses on smooth and rough cylinders with square cross sections, either with sharp edges or having rounded edges with a non-dimensional radius of r/D = 0.16, for Reynolds numbers in the range of 40,000 up to 10 million. Whereas for the sharp-edged cylinder case, only two non-dimensional surface roughness values – smooth with $k_s/D = O(10^{-5})$ and slightly rough with $k_s/D = O(10^{-3})$ – are investigated, the detailed influence of a finer variation of the surface roughness height in the same range is studied for the rounded cylinder. Using piezo-electric balances the mean and fluctuating aerodynamic forces and the vortex shedding frequency are obtained, whereas the near-wake profile is measured with a wake rake. In addition, each model is equipped with 36 static pressure taps distributed along the complete circumference of the model's mid-plane section for a detailed measurement of the mean surface pressure distribution, out of which the boundary layer separation points and the base pressure are extracted. Based on these detailed results more wind tunnel testing has now already been scheduled for the next few years to study the movement- and flow-induced instabilities in flows over rounded square-section cylinders in single and double arrangement undergoing either pure harmonic pitch or combined pitch-plunge motions at realistic Reynolds numbers.