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ANALYSIS OF WIND-INDUCED VIBRATIONS IN SILO GROUPS

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During a storm, wind-induced ovalling vibrations were observed on several empty silos of a closely spaced silo group in the port of Antwerp (Belgium) [1]. These silos have a diameter of 5.5 m, a height of 25 m and a wall thickness varying from 10.5 mm at the bottom to 6 mm at the top. The group consists of 8 by 5 silos in an in-line arrangement with a pitch of 5.8 m, mounted on top of a building that is 16.7 m high.

Figure 1: Silo group in the port of Antwerp (Belgium).

In this work, unsteady, three-dimensional computational fluid dynamics (CFD) and fluid-structure interaction (FSI) simulations are used to analyse these flow-induced vibrations. The CFD simulations consider the silos as rigid structures, while the FSI simulations take into account the interaction of the wind field with the structural vibrations. The turbulence in the wind flow is modeled with delayed detached eddy simulations (DDES) and the profiles at the inlet of the domain are created with a spectral synthesizer.

To distinguish between flow-induced vibrations due to fluid-elastic instability and vibrations triggered by vortices or turbulence in the flow, both one-way and two-way FSI

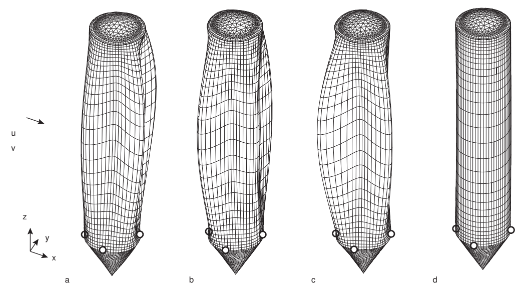

Figure 2: Snapshot of the deformation at the corners of the group, magnified by a factor 40.

simulations are performed. In the one-way FSI simulations, the aerodynamic pressures from the CFD simulations are imposed as transient external loads on the finite element models of the silos. In the two-way FSI simulations, the fluid and structural solvers are coupled by performing iterations between them using the IQN-ILS technique [2]. Consequently, vibrations due to vortices or turbulence in the flow are captured by the one-way FSI simulations, whereas fluid-elastic instability can only be detected with the two-way FSI simulations.

For a single silo as well as for the silos in group arrangement, it is found that the structural mode shapes with the lowest natural frequencies are excited. Furthermore, the largest vibrations are present at the windward side of the group. This coincides with the observed vibration patterns during the storm. The results of these 3D simulations also show that previous 2D simulations [3] did not capture the complex flow field around the silo group correctly.

The one-way simulations predict lower than expected vibration amplitudes. By switching from one-way to two-way simulations, the difference in vibration amplitudes is small for a single silo, whereas the vibration amplitudes increase significantly for the silo group, to a level similar as observed for the one in the port of Antwerp. This indicates that single silos and silos in a closely spaced group behave differently and that fluid-elastic instabilities should be considered when designing silo groups.

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