AERODYNAMIC LOAD IN SILO DESIGN

M. S. Junior. Antonio[1], K. Stuepp. Beatriz[1], Santos. Diego[1], K. L. Kzam. Aref[1]

[1]*Latin American Institute of Infrastructure and Territory Technology. Federal University of Latin American Integration. Lorivo Commercial Building - Av. Silvio Américo Sasdelli, 1842 - Vila A, 85866-000, Foz do Iguaçu - Paraná, Brazil.*
ams.junior.2018@aluno.unila.edu.br, bik.stuepp.2018@aluno.unila.edu.br, d.santos.2018@aluno.unila.edu.br, aref.kzam@unila.edu.br.

Abstract. Metal silos are thin structures composed mostly of steel sheets intended for grain storage. When empty and exposed to wind action, they are susceptible to the phenomenon of instability, thus characterizing the critical state of the structure. The instability of these profiles occurs from the formation of vibration modes leading to loss of local stability. To guarantee the integrity of the structure, transverse stiffeners are added, increasing the rigidity of the steel profiles. The present work consists in the modeling of a park of metallic silos submitted to the aerodynamic action of the wind for the analysis of the structural behavior will be considered the formation of vortices and turbulences in the empty structure, submitted only to its own weight, as well as, with the pressure coming from of your storage. For this, the structure was modeled in software based on the finite element method. The knowledge of the dynamic forces in light profile structures is essential to guarantee the integrity of the silos.

Keywords: silos, winds, stability, finite elements.

1 Introduction

Silos are structures widely used for the storage of grains, seeds and cereals, their storage capacity varies according to the material stored, as well as their structural stability. Rigid shell structures, such as silos, have several applications in the field of engineering and are efficient structures to resist dynamic forces from the wind. Reinforcement rings are mainly used to increase resistance to buckling caused by external pressure, while uprights have the function of resisting buckling (BARUCH and SINGER, 1963).

The size of the silos varies according to the material stored from 10 tons to 100,000 tons. The silo walls are designed to withstand compressive stresses in the direction parallel to the walls and tensile stresses in the circumferential direction. (SONDEJ, IWICKI and TEJCHMAN, 2015).

Determining bulk solids loading during silos filling and unloading should be the first step in structural design design. When empty, the silos are susceptible to deformation of the metal sheets by the action of the wind. The evaluation of the instability of this type of structure is essential, due to the small thickness of the wall and the asymmetric loads that act on it. (MALEKI and MEHRETEHRANY, 2018).

According to studies carried out by Zhao, Cao and Su (2013), the buckling behavior of steel silos, subject to wind pressure, varies according to the height/diameter and radius/thickness ratios. The buckling resistance of silos under wind pressure increases significantly with decreasing height/diameter and radius/thickness ratios.

Maleki and Mehretehrany analyzed that corrugated and smooth sheets have different buckling resistance. According to the authors, for corrugated sheets, the corrugation depth is the main resistance parameter, while the wavelength is less representative in the resistance. Isolated and grouped wind loads result in different buckling modes. In the case of single loads, shear wrinkles develop at the base of the silos, on the windward side, such wrinkles did not develop under the action of grouped loads. (MALEKI and MEHRETEHRANY, 2018)

In the present study, through the computational modeling of a park of corrugated cylindrical silos, with a conical cover and with a height/diameter ratio equal to 1.27, the behavior of these structures subjected to dynamic forces is analyzed. it is possible to verify the presence of vortices resulting from the action of the wind, their influence on the resistance and how they are distributed in the structure in case it is filled or empty.

2 Methodology

The 3D modeling of the silo park analyzed in this article was performed using AutoCAD 3D software, such software allows the import of the model into Ansys for computational analysis. In order to simulate the action of the wind on the structure, it was necessary to model a control volume. The control volume consists of a parallelepiped of dimensions whose height and width of the entrance face are of the order of up to 5x the height of the building. The length of the control volume is on the order of 15x the height.

Once the control volume is created, the construction contour is subtracted from it, filling it later with the solid that represents the silo structure. The solid created in AutoCAD 3D was exported as an ACIS file to be used as an external reference for the project.

To simulate the action of the wind on the structure, Ansys software was used with the resources of the workbench. Within the workbench, the FluidFlow (CFX) analysis system was used. In the workbench, the solid created in AutoCAD was imported through Designer Modeler, changing the measurement units to millimeters, the same used in the creation of the model. All sides of the control volume were characterized, both the inlet and outlet of the fluid (wind, in this case).

The finite element meshes were created according to the default settings pre-established within the software. The fluid simulation model used was the RNG K-Epsilon, which consists of a numerical method to solve the Navier-Stokes equations that describe the flow of fluids.

After modeling, the boundary conditions of the control volume and implanted solids are defined. The wind speed used in the simulation was 50 m/s. The minimum number of iterations considered in the simulation was 100 and the maximum 300. During the processing, it was decided to use double precision.

3 Results

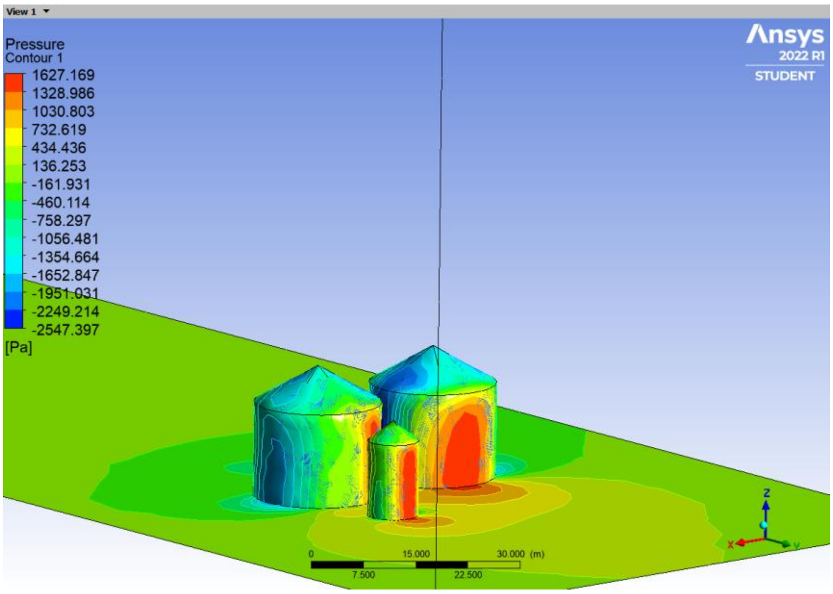

Figure 1. Diagram of pressures including ground interference.

The pressure fields formed can induce instability in the silos closing profile, requiring the implementation of stiffening rings. It is observed that the pressures are greater at the base of the silos, which may cause the base to pull out of the foundation structure, thus requiring reinforcement in the foundations.

In addition to the pressures on the structure, the current lines generated by the wind, their speeds and the possible formation of vortices were analyzed as shown in Figure 2.

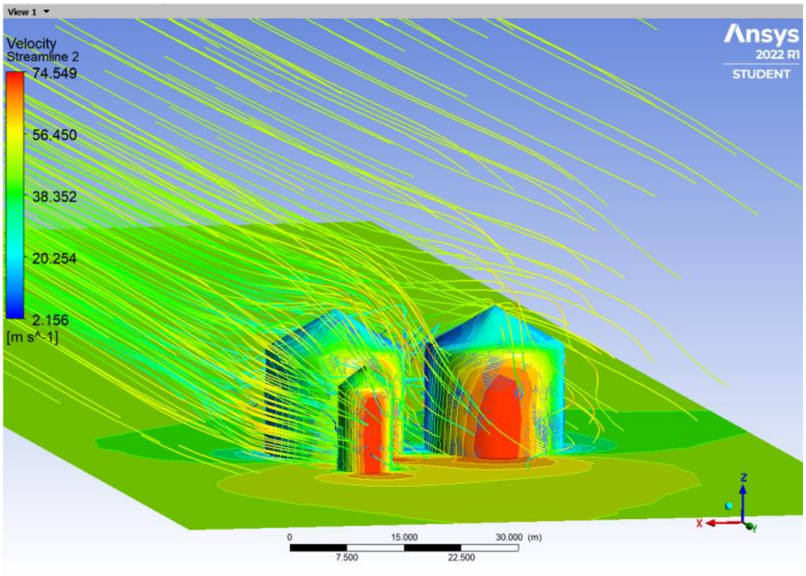

Figure 2. Streamline behavior with 100 points.

One can observe the formation of vortices between the silos. The vortices produce an overpressure on the structure, if the structure does not support it is necessary to carry out the replacement of the profile or the stiffening of the same.

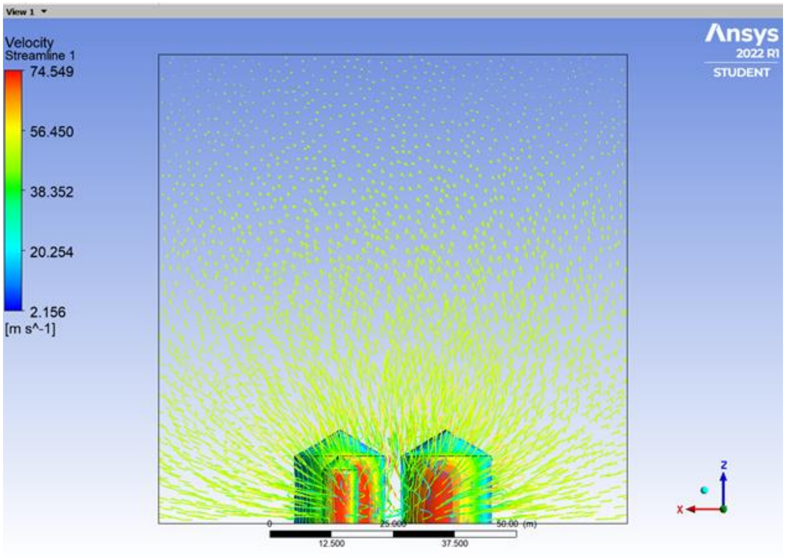

Figure 3. Front View Streamlines

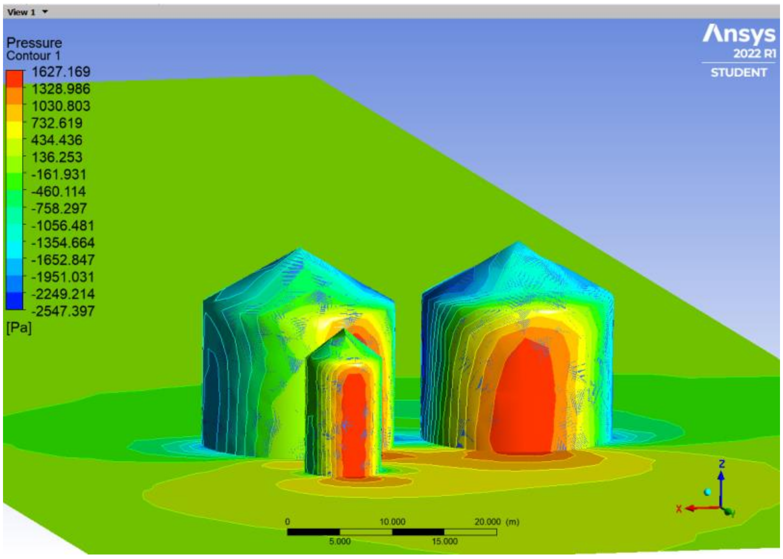

Figure 4. Diagram of pressures.

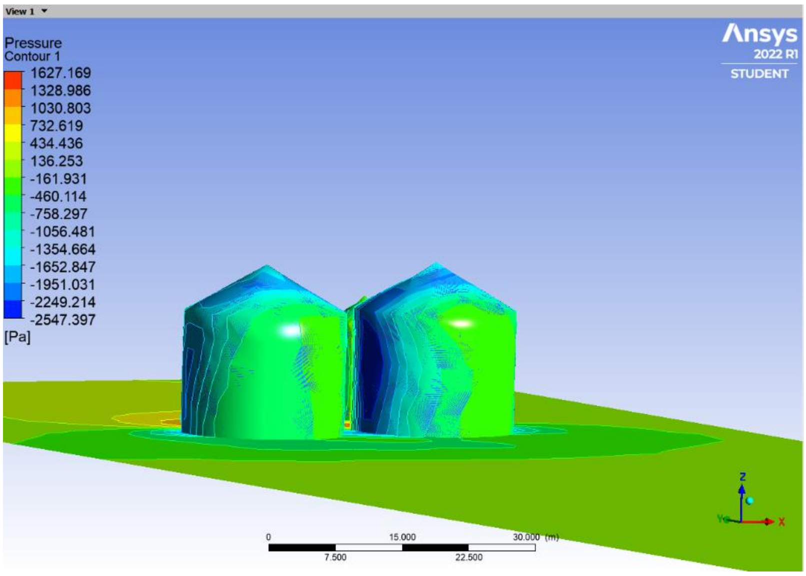

Figure 5. Suction Pressure Diagram.

4 Conclusions

With the development of this work, it was possible to show how the positioning of the silos inside the park can contribute to the formation of vortices that increase the external pressure on the structure's sheet. The region most affected by the incidence of wind is the face that is directly on the direction in which it acts, its pressure is directly related to the silo diameter that influences the distribution of efforts.

The conical cover of the structure proved to be efficient from an aerodynamic point of view, dissipating wind pressure more smoothly. The study of soil-structure interaction in this case is essential, since in situations where the silo is empty, the stresses on the foundations could be traction, since when it is at full storage capacity, compression must be the type of effort predominant.

For future studies, a more thorough evaluation of how the distance between storage units can influence the generation of vortices and reduce possible overpressures is recommended. In addition, possible analyzes of how commercially available diameters perform when subjected to dynamic stresses.

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