Wind vulnerability of industrial facilities equipment

Nahuel Bonfante [1], Jean-Paul Pinelli [2]

[1] *Florida Institute of Technology, Melbourne, US, nbonfante2023@my.fit.edu*
[2] *Florida Institute of Technology, Melbourne, US, pinelli@fit.edu*

SUMMARY:
The authors, with support from the Wind Hazard and Infrastructure Performance Center (WHIP-C), are developing wind vulnerability models for refineries. These facilities cover large areas with varying wind conditions and infrastructure types, such as tanks, pipe racks, and power stations. The goal is to standardize the methodology for assessing wind vulnerability, addressing inconsistencies in current approaches.

The methodology decomposes a refinery into subsystems, each representing different equipment types like tanks or pipe racks. For each subsystem, a conventional risk model is applied, following the principle "one site, one hazard, one vulnerability." These models are then combined based on intercorrelations between subsystems, using a “LEGO” approach that allows flexible integration of equipment vulnerabilities into an aggregated model.

Vulnerability matrices and curves are key to this method. Each matrix quantifies damage probabilities at various hazard intensities, while vulnerability curves plot expected damage against hazard intensity. By focusing on tanks and pipe racks, the study defines taxonomies and characterizes their vulnerabilities.

Preliminary results include mapping 48 processes and 71 product flows from a refinery's Process Flow Diagram (PFD), aiding in the evaluation of overall system vulnerability. Further findings, including vulnerabilities, shall be presented at the conference.

Keywords: Wind Vulnerability, Refinery, Risk Model, Equipment Classification, Industrial Networks.

1. MOTIVATION

The authors, with the support of the Wind Hazard and Infrastructure Performance Center (WHIP-C), are developing wind vulnerability models for large industrial facilities, such as refinery plants. These, and other industrial plants, are key elements of regional and country wide economies. Damage to these plants can have serious consequences for economic prosperity, as well as for human safety and wellbeing, and the environment, through the potential for natech incidents (technological incidents triggered by a natural hazard).

2. METHODS

This research presents numerous challenges, as these facilities are spread over vast areas that can exhibit significant variations in wind speeds, surface friction, topography, and other factors. Moreover, the infrastructure components of these facilities can vary greatly, including power stations, pipe racks, tanks, warehouses, cranes, towers, and more.

The authors decompose a refinery into several subsystems corresponding to its different equipment. for which conventional risk models can be applied: one site, one hazard, one vulnerability. These models will then be combined (though not necessarily added) based on the intercorrelations between the subsystems. In this so-called "LEGO" approach, typical vulnerability equipment can be plugged in and interconnected, much like LEGO blocks, to produce an aggregated wind vulnerability model for the entire system.

The primary focus of this research lies in the development of wind vulnerability matrices and curves for refinery equipment and structures, which serve to quantify and assess the susceptibility to wind-induced damage. The columns of a vulnerability matrix are probability density functions (pdf) of damage conditional on different hazard intensity intervals (each column represents a different intensity interval). The vulnerability curve plots the expected damage for each column pdf as a function of hazard intensity. Vulnerability matrices and curves are commonly used to estimate potential economic losses by correlating hazard intensity with a specific loss metric.

The most vulnerable equipment, and therefore the focus of our study, are the tanks and pipe-racks, The study starts with detailed taxonomies of tanks and pipe-racks within refineries, which translate into the characterization of different classes for each type of equipment. The taxonomies also inform the nomenclature that identifies each class of equipment for which we define a vulnerability model. By characterizing all equipment into different classes based on their corresponding taxonomies and having established the vulnerabilities of each equipment class, we will achieve a comprehensive understanding of the vulnerability of the equipment in the refinery.

A refinery Process Flow Diagram (PFD), as shown in Figure 1, is an essential documentation for its operation. The PFD illustrates all the processes, each of which involves one or more equipment, and each equipment has its own taxonomy, and for which we have already defined vulnerability based on their type and class. What is particularly interesting is that it also shows the interconnections between these processes. This allows us to define a workflow, understanding the equipment involved and the vulnerabilities associated with each equipment, as well as the overall vulnerability of each process flow within the refinery. By weighting and interconnecting the vulnerabilities of each flow, we can determine the overall vulnerability of the refinery.

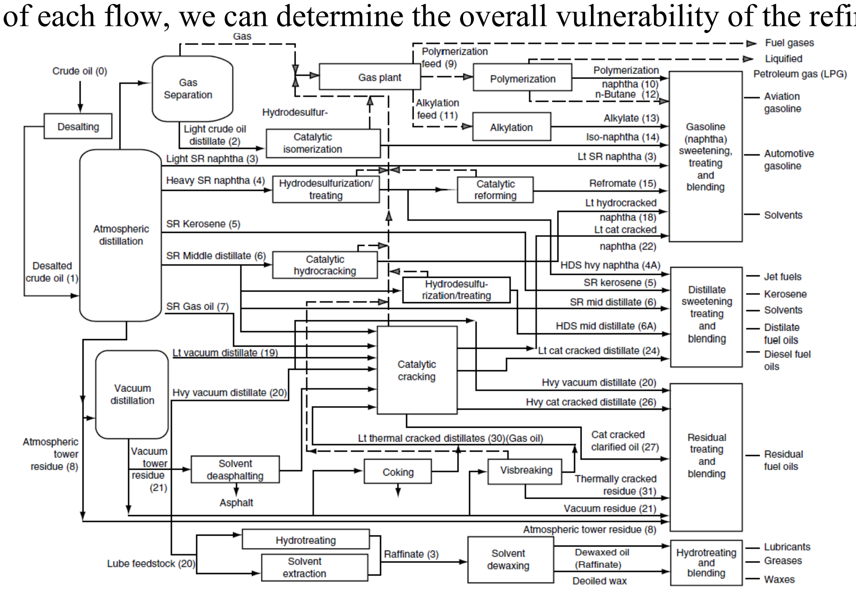

Figure 1. Schematic overview of a refinery. From OSHA (Occupational Safety and Health Administration) from USA, Technical Manual, Section IV, Chapter2, Petroleum Refining Processes.

3. RESULTS

A typical refinery PFD, as defined by the USA Occupational Safety and Health Administration (OSHA), was used to identify and map 48 key processes and 71 unique product flows. Processes were categorized by equipment type, and tanks and pipe-racks were classified into distinct categories (see Figure 2). A new nomenclature captures the taxonomy of the equipment related to wind vulnerability. Vulnerability curves for various tank types and pipe-racks, which are essential to refinery operations, are currently under development and shall be presented at the conference.

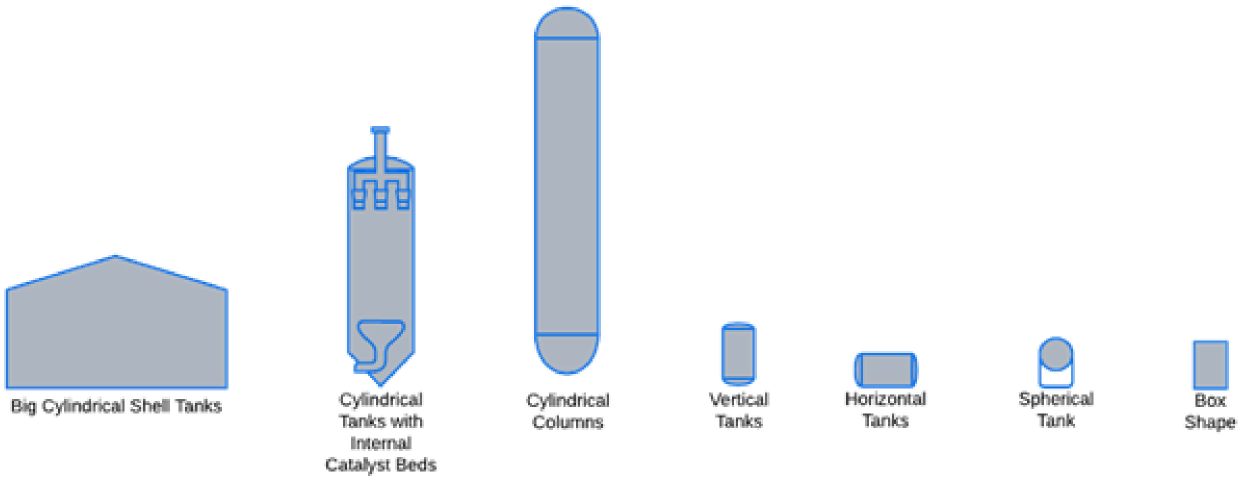

Figure 2. Tank Classification.

4. CONCLUSIONS

This research will provide a standardized approach to wind vulnerability modelling for refineries and large industrial facilities. By systematically classifying and characterizing equipment and processes, this work sets the foundation for more accurate and unbiased assessments of wind-induced damage. Results will be presented at the conference, including the mapping of crude oil process flows, equipment vulnerability, and a fully developed nomenclature. Future work will refine these models and address the issues of network vulnerability, validation and uncertainty quantification.

5. ACKNOWLEDGMENTS

The authors would like to thank the Wind Hazard and Infrastructure Performance Center (WHIP-C) for their support.

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