COMPUTATIONAL FLUID DYNAMICS SIMULATION COUPLED WITH VIRTUAL REALITY: AN APPLICATION FOR PROCESS SAFETY

Tássia L. S. Quaresma[1], Luis Felipe J. A. Maximiano[2], Sávio S. V. Vianna[3]

ABSTRACT

Computational Fluid Dynamics (CFD) is a widely used approach to accurately represent and predict the fluid flow behavior for several cases in the process industry. As large amount of data is generated from sophisticated CFD simulations, flow visualization becomes convenient to better understand fluid flow phenomena. Virtual reality (VR) has been associated with CFD simulations, leading to the development of immersive virtual environments (VE) that has significantly enhanced the overall comprehension of CFD results. VEs contribute to an effective visualization of the phenomena for both CFD experts and non-experts, by allowing a realistic interaction between the user and the computer-generated environment. This paper proposes an integrated computational tool based on Virtual Reality and CFD simulation for visualization of vulnerable area in case of accidental gas release and pool fire. Within the approach different scenarios of gas dispersion and pool fire in a process area has been simulated by using ANSYS CFX CFD tool. A post processing is applied to represent the CFD simulation results into a VR software. Interactive section view selection and time-step animation methods are applied for intuitive interaction with the VR environment. The VR system is developed with the Unreal Engine 4 open software and a mobile device. Demonstration in some typical scenarios of gas dispersion shows that the proposed method and prototype system provide an intuitive and fluent VR-based environment for interactive vulnerable process area visualization. The developed tool emerges as a disruptive model to process safety team training.

1. INTRODUCTION

Computational fluid dynamics (CFD) simulations are commonly used in process safety to predict fluid flow behavior with satisfactory accuracy. Accidental releases of flammable gas in industrial plants can potentially escalate to catastrophic events such as fire and explosion. In this sense, CFD can be used to determine the vulnerable area resulted from gas release scenarios and this knowledge can be applied to safety training purposes within industrial environment.

More recently, the virtual environment has been consistently applied in the industry, optimizing the design and operational procedures. In addition, the youngest generations are well familiar with this kind of technology which allows for more effective ways of training.

Therefore, making the most of both worlds, (CFD and VR environment), this work is based on an accidental release of methane at an industrial plant of an onshore gas processing unit. The geometry of the industrial plant was modeled both in ANSYS CFX for CFD simulations and in Unreal Engine 4 (UE4) to build the game environment. Gas release was first simulated using ANSYS CFX, considering different wind directions in order to cover the most likely cloud displacement scenarios. CFD simulation results were applied in the game environment in order to define the vulnerable area. Following this line of reasoning it was possible to establish critical zones based on the state of knowledge as far as the CFD modeling is concerned.

This paper is organized as follows: next section presents an overview of the methodology applied, followed by the results obtained and the last section draws the conclusions.

2. DESCRIPTION

The work methodology comprised three main phases: geometry modeling, CFD simulations and

1 Master Student – UNICAMP
2 Scientific Initiation Student - UNICAMP
3 Professor PhD - UNICAMP

game development. CFD simulations were performed on ANSYS CFX which is a reliable and leading software for fluid flow behavior simulations. The game has been developed with the Unreal Engine 4 (UE4), a free software suitable for advanced game developers.

The geometry, based on a onshore gas processing unit, was first modeled in ANSYS CFX and then reproduced in UE4. An accidental release of methane was simulated on ANSYS CFX, considering different wind directions. The influence of wind direction on the flammable cloud was evaluated for the directions xlow, ylow, xhigh and yhigh.

3. DISCUSSION

This section presents the results obtained for geometry modeling, meshing and CFD simulations.

3.1 Geometry modeling and meshing

The industrial plant based on a gas processing unit was modeled both in ANSYS CFX and then in Unreal Engine 4, as it can be seen on Fig. 1. It is noticed that both geometries present a high level of similarity, in such a way that the game is able to reproduce the CFD environment with good fidelity.

A **B**

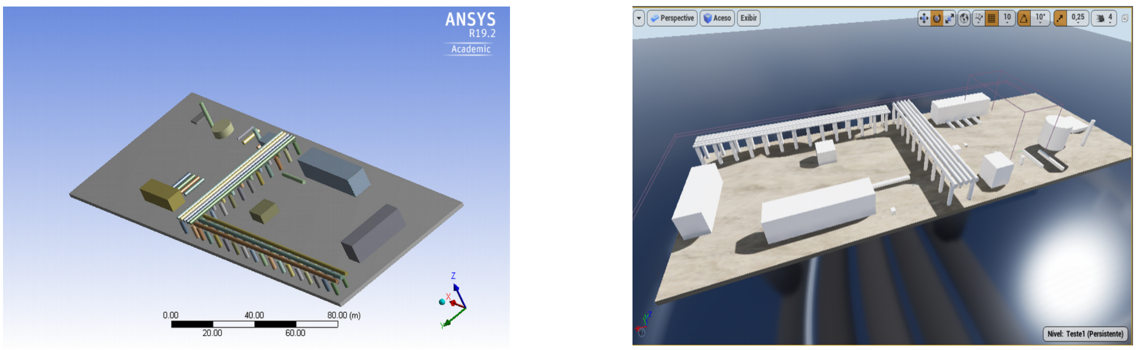

Fig. 1 – Geometry modeling based on a onshore gas processing plant. A – Geometry in ANSYS CFX; B – Geometry in Unreal Engine 4.

After geometry modeling, meshing was generated using ANSYS CFX. Regions in the proximity of solid elements present a higher level of refinement for enhanced precision of numerical calculations, as it can be seen on Fig. 2.

A **B**

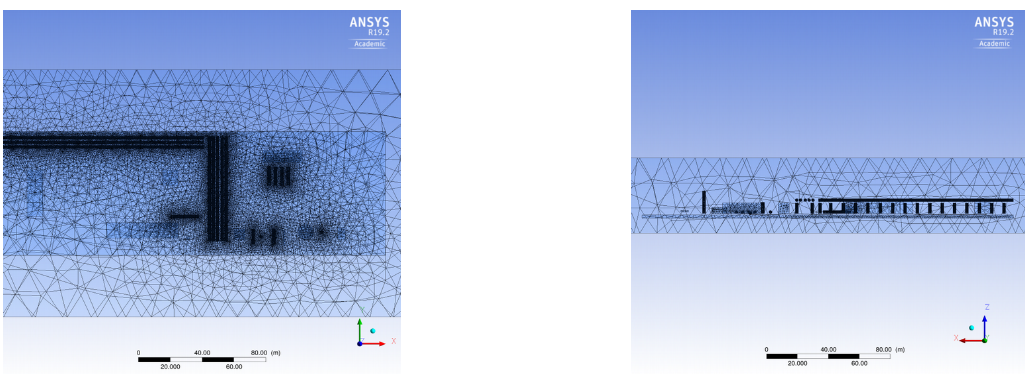

Fig.2 – Computational mesh over geometry, obtained in Ansys CFX. A – superior view; B – side view.

3.2 CFD simulations using ANSYS CFX

Methane release was simulated considering four different wind directions in order to evaluate the influence on flammable cloud formation. Fig. 3 brings the methane flammable cloud isosurfaces and mass fractions according to wind directions of xlow, ylow, yhigh and xhigh, respectively.

After covering typical wind directions that can influence the flammable cloud extension, a vulnerable region could be determined.

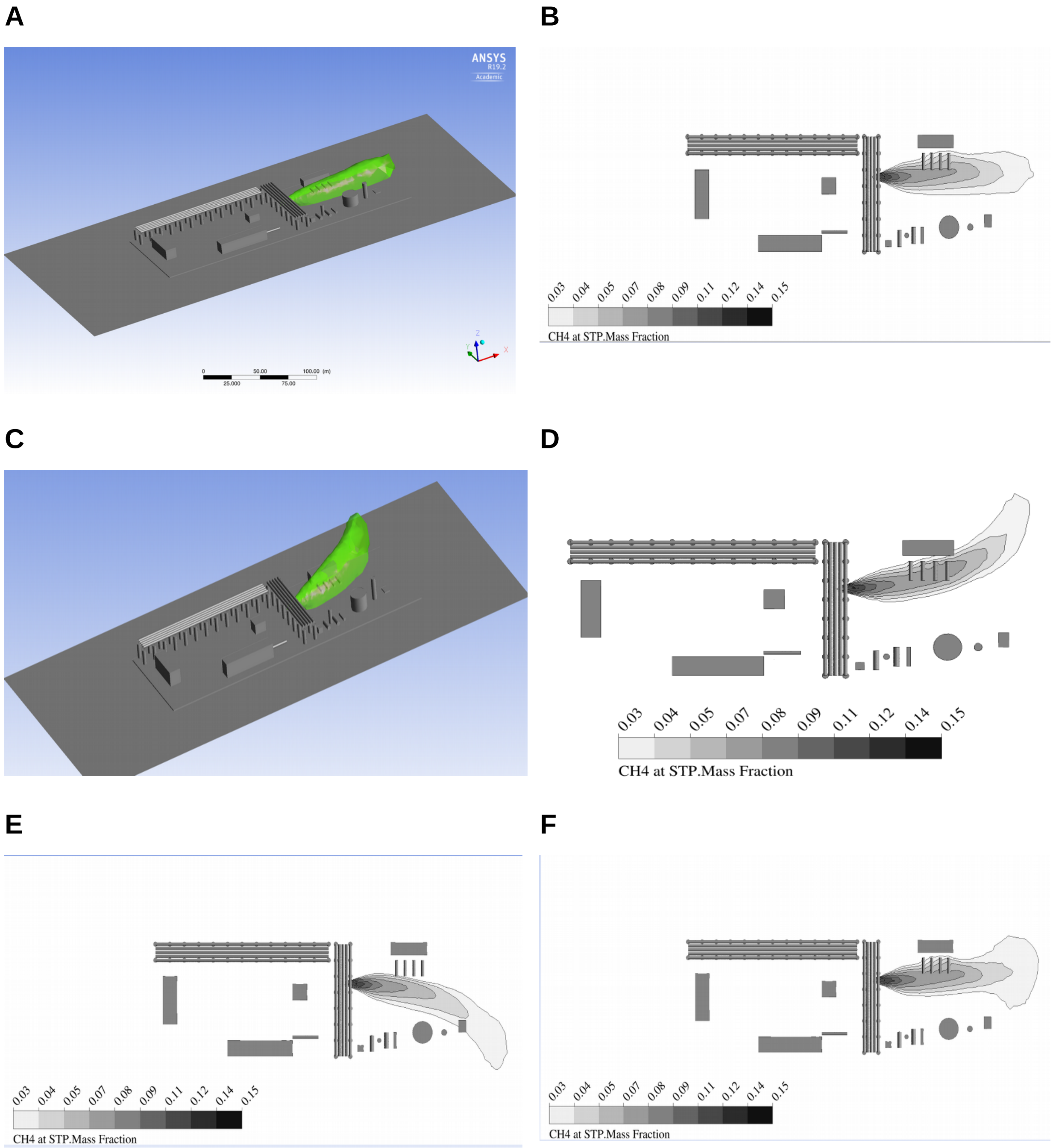

Fig.3 – Flammable cloud of methane, CFD simulations. A: cloud isosurface, wind direction xlow; B: methane mass fraction, wind direction xlow; C: cloud isosurface, wind direction ylow; D: methane mass fraction, wind direction ylow; E: methane mass fraction, wind direction yhigh; F: methane mass fraction, wind direction xhigh.

3.3 CFD simulations results coupled with VR environment

The vulnerable area obtained with CFD simulations of the flammable cloud is then delimited on the VR game environment (Fig. 4A). Once the geometry and the vulnerable area is set up, a character is introduced on the scene, representing a process operator that needs to escape.

The game starts with the character positioned in such a way that the leakage can be observed (Fig. 4B). Smoke and soot are added to the game scene to illustrate the leakage area. The objective is to move the character around the industrial plant to escape without reaching the vulnerable region.

A **B**

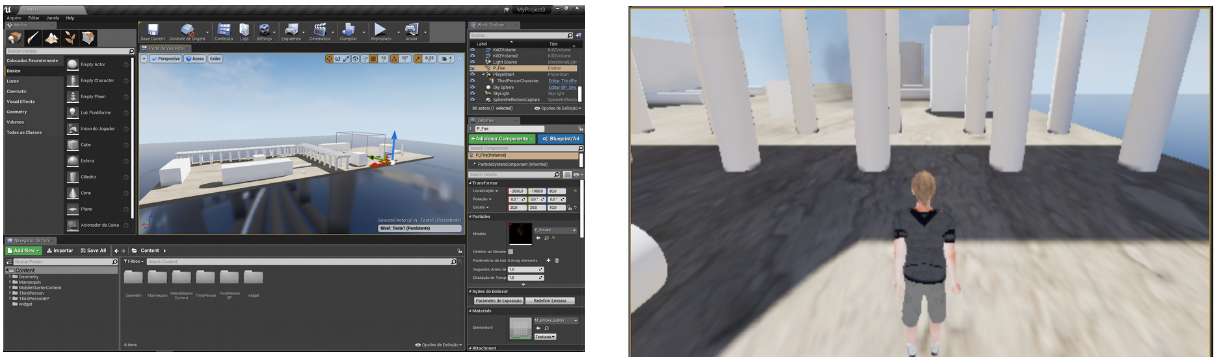

Fig.4 – Training simulator developed in Unreal Engine. A – Unreal Engine interface; B – Starting point of Vulnerability Training Simulator

The software UE4 allows for the game to be exported to mobile devices such as cellphones, tablets and glasses for virtual reality headsets. However, at this stage of the project the game was exported to a mobile phone, where the user can handle it in a much interactive manner.

4. CONCLUSION

Loss of containment of flammable gases at industrial plants are likely to affect the integrity of people and process continuity. Being able to safely isolate the affected area is a crucial part of mitigation measures that need to be accurately performed in order to avoid the escalation of events. In this sense, VR environment games coupled with CFD simulation results of leakages can be an useful tool for escape training.

5. REFERENCES

SOARES, Paulo Renato Ferreira Targino. Realidade virtual como ferramenta de treinamento para brigada de emergência de uma refinaria. 2019. Dissertação de Mestrado. Universidade Federal de Pernambuco.

ÇENGEL, Yunus A.; CIMBALA, John M. Fluid Mechanics: Fundamentals and Applications, 4e in SI Units. McGraw-Hill Education, 2019.

Cha, M., Han, S., Lee, J., & Choi, B. (2012). A virtual reality based fire training simulator integrated with fire dynamics data. *Fire Safety Journal*, *50*, 12-24.

CENTER FOR CHEMICAL PROCESS SAFETY (CCPS). Guidelines for Chemical Process Quantitative Risk Analysis. [S.l.]: John Wiley Sons, Ltd, 2000. ISBN 9780470935422.