CONSTRAINTS AND CONSEQUENCES IN 3-DIMENSIONAL CFD MODELING OF OPEN-PIT MINES

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ABSTRACT

Computational fluid dynamics (CFD) modeling of an open-pit mine has several challenges. A good quality mesh of the model domain is a pre-requisite for convergence in solution. Good quality tetrahedral meshing and insertion of prism layers in faceted open-pit mine geometry is complicated due to presence of numerous vertices and ridges. Presence of vertices and ridges result in poor quality tetra elements and holes in prism layers, which cause instability in the model. Good quality pit bottom prism mesh elements significantly improve the formation of velocity boundary layer and thermal boundary layer at the pit bottom. This results in an expected temperature dependent micrometeorological buoyancy flow in the pit. Whereas, model geometry without a prism layer, results in abrupt temperature gradient near pit bottom. Buoyancy flow and recirculation have significant effect in lifting mechanism of fugitive dust particles generated near pit bottom. Representative initial and boundary conditions and selection of appropriate turbulence model have significant influences on the simulation results. In this paper, three-dimensional models of open-pit mines are developed using commercial CFD software (CRADLE-CFD). Important constraints and various consequences in modeling complex open-pit geometries are presented.

INTRODUCTION

Application of Computational fluid dynamics (CFD) to model an open-pit mine to predict fugitive dust and pollutant concentrations in and around a mine is relatively new. In former Soviet republic (USSR), Baklanov [1] and Belousov [2, 3] presented numerical models of pollutant transport in open-pit mines in Arctic regions. In recent years, advances in mathematical and computational fields have enabled better modeling of pollutant dispersion phenomenon around mines using computational fluid dynamics (CFD). Several CFD software packages have been used by various researchers to model the pollutant transport in open-pit mines.

Works by Alvarez et al. [4]; Lowndes et al. [5]; Silvester et al. [6]; Torno et al. [7]; Choudhury and Bandopadhyay [8]; Collingwood et al. [9]; Raj et al. [10] and Flores et al. [11]; are examples of application of various commercial and open source CFD packages (COMSOL, ANSYS, OpenFOAM) to model pollutant transport in open-pit mines. These researches provided a strong background for additional research involving CFD modeling of open-pit mines. Due to the limitations of computational times and capacity, 3D modeling and various aspects of fugitive dust dispersion in open-pit mines remained unexplored.

In this study, the development of a 3-Dimensional fugitive dust dispersion model using CRADLE-CFD package is presented. For modeling a large open-pit mine with faceted and sharp features in the geometry and complex topography, the SC/Tetra software package of CRADLE-CFD provides many advantages in comparison with other commercial CFD software (ANSYS, COMSOL). Robustness in meshing, high speed meshing, high speed calculations with competitive resolution and overall efficiency of the software in comparison with the computational capacity and time requirement of COMSOL or ANSYS; have significant influences in reduction of computational lead time. [16]

GEOMETRY IMPORT

The model domain for 3-Dimensional CFD modeling of an open-pit mine is a 3-Dimensional volume bounded by several boundaries. Development of a CFD model of a domain involves: (i) Preprocessing, (ii) Solving and (iii) Post-processing. In the preprocessing stage, a 3-Dimensional volume of open-pit geometry is imported into the Preprocessor. This volume is often generated in CAD software using scanned open-pit mine geometry. Figure 1 shows an actual open-pit geometry imported into CRADLE SC/Tetra Preprocessor. The model domain includes triangulated mine surfaces; and the other boundaries such as East, West, North and South are created perpendicularly at the four edges of this topography. Free-Atmosphere (FA) boundary is added at the top, to enclose the complete volume. The Preprocessor can import geometries of various formats such as NASTRAN (.nas), ANSYS (.cdb), CGNS (.cgns) and DXF (.dxf).

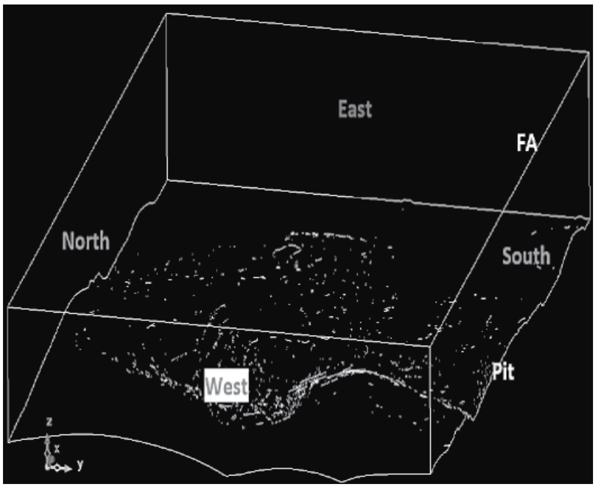

Figure 1. 3D Model of the mine and various boundaries.