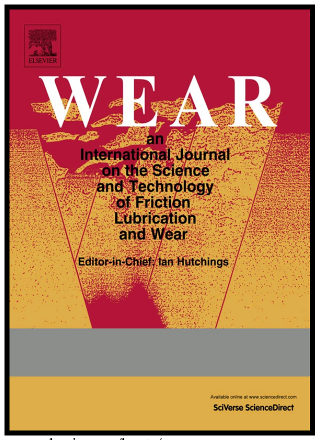

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Application and experimental validation of a CFD based erosion prediction procedure for jet impingement geometry

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Abstract

Computational Fluid Dynamics (CFD) based erosion prediction procedures are carried out to predict erosion for a submerged liquid jet impingement geometry. 3-D modeling with different near wall treatments are employed to simulate the wall bounded turbulent jet flow. Discrete Phase Model (DPM) is applied to track particles and obtain particle impact characteristics. Erosion is calculated using typical erosion ratio equations in the literature [1]. In this paper, two categories of near wall modeling approaches (wall functions and near wall models) are presented and examined. Particle impact parameters are extracted and compared with measured data to determine the most accurate near wall modeling approaches. A procedure for grid refinement particular for erosion simulations is proposed and followed by uncertainty analysis from the CFD predictions. Experimental data with uncertainty quantified for 300 μm large particles and 25 μm small particles are utilized to validate the proposed procedure. It is shown that following the proposed procedure yields very good erosion prediction from CFD regardless of particle size.

Keywords: CFD; Erosion; Near-wall modeling; CFD based erosion modeling procedure; Uncertainty analysis

1. Introduction

Being able to predict solid particle erosion is of significant importance to many industries including mining and oil and gas production. Computational Fluid Dynamics (CFD) has been widely used to predict erosion caused by solid particles. This technique consists of three components which are flow modeling, particle tracking and erosion calculation through erosion ratio equations. It has been acknowledged that the grid utilized in this technique affects both flow modeling and particle tracking [2], [3]. With respect to flow modeling, grids used, particularly in the near wall regions, affect the resolution of the near wall flow field. A coarse mesh is often used together with wall functions to approximate the near wall mean flow and turbulence field. This approach may be unable to provide sufficiently accurate flow field information in the region between the first near wall cell layer center and the wall. A fine mesh with near wall models, however, can solve the near-wall flow field all the way to the wall with boundary layer adequately resolved.

Particle tracking also relies on the grids being used to calculate the flow field. A particle is re-located based on mesh topology information and advanced cell by cell. In turbulent flow, turbulent dispersion of particles is often modeled by an eddy interaction model (EIM) [4] in which particle dispersion is determined by a particle interacting with a succession of eddies of which velocity and time scales are calculated based on turbulent quantities within the local cell while the mean fluid velocity is constant. Currently, in most commercially available CFD codes that contain particle tracking procedures, particles are treated as a point mass in the algorithm. This treatment of particle size has several drawbacks in the present particle tracking models particularly near the wall with application to small particle erosion prediction [5].

An erosion ratio equation is often used to convert erosive particle impacts to material damage. The accuracy of this equation is also a crucial component that determines the confidence of predicted erosion. There are many erosion ratio equations in the literature. Most of them are derived with the approach of erosion testing and curve-fitting which may limit the application of erosion ratio equations to the range of experimental conditions. Some erosion ratio equations can be very conservative while others are not. The discussion of different erosion ratio equations is complicated and requires a large erosion data bank to draw a conclusion which is beyond the scope of this paper. However, this paper can serve as a further progress to evaluate the applicability of a typical Erosion Corrosion Research Center (E/CRC) Angle Dependent Model for different geometries and particle sizes.

Many CFD practices with application to erosion simulation exist in the literature. However, most of them do not involve a comprehensive evaluation and validation of CFD predictions versus experimental data [6]-[8]. Some good predictions can be obtained fortuitously as erosion is a function of multiple factors and different factors may offset each other to obtain good results. Whereas, key issues like conducting systematic grid refinement studies for CFD based erosion simulations while ensuring accurate prediction of particle impact parameters are seldom discussed and