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CFD Modeling of Material Erosion: A Review

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Abstract: **Estimating the material erosion rate caused by the solid particle laden flow is a critical aspect with respect to the safety and performance of the systems. Applying the computational fluid dynamics (CFD) methods for predicting material erosion is gaining popularity. In this paper, the various aspects related to the CFD simulation procedure for modeling the material erosion had been discussed. Based on the available literature, a comprehensive simulation practices for the erosion modeling such as selection of Boundary conditions, One Way / Two Way Couplings between the solid and fluid phase, particle impact angle, Turbulence modeling, CFD Meshing standards, convergence criteria, influence of Wall Roughness, Particle injection profile, erosion for multiple geometries like elbows, were discussed.**

Keywords: **CFD Modeling, Estimating the material erosion rate.**

1. INTRODUCTION

Material erosion caused by the solid particle laden flow is a critical design aspect in the fields of petro-chemical, piping, valves e.t.c. It is essential to estimate the material erosion rate as part of the engineering design. The material erosion can be estimated either by the experimental studies or by numerical simulations (CFD). Experimental studies may prove to be providing reliable results for the material erosion. However, the complex procedure associated with experimental set-up, time required for performing the experimentation are certain drawbacks in the experimental approach towards the material erosion cases. On the contrary, the CFD simulations for performing the material erosion is relatively easier, less time consuming along with a possibility of detailed result analysis. However, the simulation accuracy depends on many user input factors and selection of appropriate models that are available in the CFD solvers. These include, selection of boundary conditions, turbulence models, required mesh resolution, modeling the influence of solid particles on fluid phase, particle injection profile, particle impact angle, identifying the appropriate erosion models such as Finnie, numerical schemes for better solution accuracy e.t.c. The user must have sufficient background knowledge on such factors to produce accurate results from CFD simulations. This paper provides a comprehensive review of the available literature on material erosion modeling using CFD.

2. LITERATURE REVIEW

SamyM.El-Behery et al [1] have performed CFD simulations for the sand erosion on the curved ducts using the Eulerian-Lagrangian approach. The influence of solid particles, sands in this case, on gas phase were considered in the simulations. Their results were validated against the experimental values, Based on their findings from the CFD simulations, they concluded that in order to avoid the failure, the flow velocity should be reduced as the mass loading ratio, particle size and the pipe diameter increase.

Gary Brown [2] had also used the Eulerian-lagrangian approach to model the slurry erosion in the pipeing system. Here, the slurry consists of Caustic liquor and Bauxite particles. His work was carried out using the commercial CFD software CFX. The geometry contains an inlet and an Outlet. The meshing was performed using unstructured mesh elements with 5 prism layers to capture the boundary layer effects.The author had used Rosin-Rammler distribution model to represent the particle distribution at the flow inlet. The simulations were carried out using the Finnie's erosion model with a One-Way coupling i.e. the solid particles were influencing the gas phase motion. The coefficient of Restitution values maintained to be 1. The results obtained in these simulations were observed to be matching with the experimentation.

Mehdi Azimian et al [3] had conducted numerical and experimental investigation of erosion in a slurry tank test rig. The authors had used CFX for the CFD simulations. Slurry consisted of Water and Sand particles. The simulation domain was split in to two rotational zones, mixer region and the rotational region of the erosion plate, and a static fluid zone. These zones were modeled using the Multiple Reference Frame (MRF) approach. They had used two hard metals, stainless steel and ST-50, under various operating conditions. The results from the simulations were in good agreement While modeling the erosion problem, the selection of turbulence models can affect the simulation accuracy as well.

Jae Hyung Kim et al [4] had studied the influence of k-epsilon and Shear Stress Transport (SST) models using the Finnie' Erosion model for Air Jet simulations. The SST model uses the blending function, with Standard K-epsilon turbulence model for the bulk flow region and k-omega model at the boundary layer region. The authors had simulated using ANSYS CFX. Erosion results from the SST model showed better accuracy as compared to the k-epsilon turbulence model.

The Wall boundary condition in a CFD simulation normally corresponds to Smooth Wall with No-Slip conditions. The roughness in the wall can impact the accuracy of the erosion simulations. This particular factor was investigated by **Christopher B Solnordal et al [5]** in their work. The authors had used the Euler-Lagrangian approach modeling the erosion. The inflow conditions were specified using the Dirichlet conditions. The walls were specified with a roughness of 16 micro meters. The numerical results were compared against the experimental values by the authors. And, such approach of specifying wall roughness resulted in prediction of better erosion rate.

Material erosion is not limited to the fields such as Oil and Gas, Piping e.t.c. In aerospace field where the components are subjected to very high flow speed environment, the erosion on Gas Turbine engines could be critical to the safety of aircrafts. **Q.B. Nguyen et al [6]** had investigated the material erosion on aerospace industries by performing experiments and numerical studies on high speed (Mach number > 3) flows. Their study focused on evaluating erosion rate for various impact angles. The have concluded that the erosion rate increases as impact angle is varied from 0 till 40° and then the erosion rate drops. The peak erosion rates were predicted by the authors, by both CFD and experimental methods, occurred at an impact angle of 40.

SamyM.El-Behery et al [1] had approached the erosion on curved ducts using 2-Dimensional approach in their CFD simulations. In their work, the flow of gas with solid particles, of Carbon Steel and Aluminum, were considered. The material erosion rate was estimated for two curved duct angles, 90 and 180. The authors had considered the influence of the solid particles on the gas phase. Also, the particle rotation and lift forces were included in their simulations. The results were in good agreement with the experimental results. The authors had concluded that the bend orientation and flow direction had no significant effect on the penetration rate.

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