Particle Comminution Using Waterjets Based Mill: Coupled CFD-DEM Study

Ontlametse Kenneth Molatlhegi
PhD. Candidate, Mining Engineering

Introduction

The high energy inefficiency of Waterjet based mill has been the focus of much of modern-day comminution research. The current study aims to develop a mechanistic model that accurately captures the process of fluid accelerating particles and predict the crushing behavior of particles inside the mill by means of numerical simulation. The most distinguished things in the current work are as follows: (a) the particle/fluid, particle/particle and particle/wall interactions are characterized by the CFD-DEM coupling method **(As shown fig 1)**. In this poster, only the results of Validated CFD model will be presented. The findings of this study could help in guiding engineering design in the future.

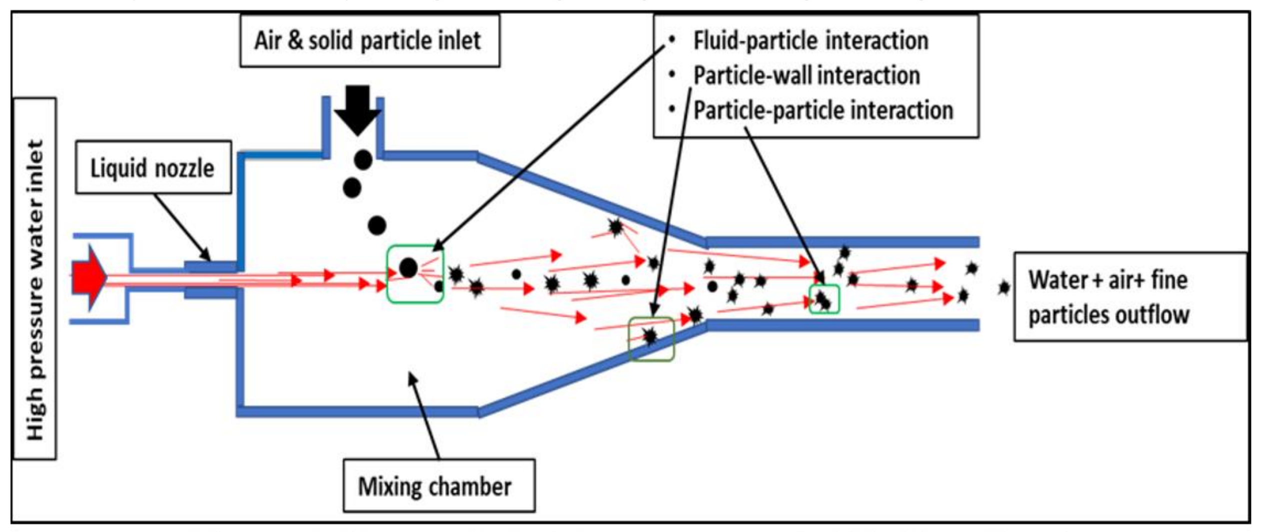


Figure 1 The particle-injection waterjet Cutting Head

Proposed Methods

The proposed model will be developed in three stages;

1. Solving for continuums phase flow (water and air) based upon CFD approach [1].

$$\frac{\partial(\alpha_a u_i)}{\partial x_i} = 0 \quad (1)$$

$$\frac{\partial(\rho u_i u_j)}{\partial x_j} = -\frac{\partial P}{\partial x_i} + \frac{\partial}{\partial x_j}\mu\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) + \frac{\partial}{\partial x_j}\left(-\rho\,\overline{u_i' u_j'}\right) + \rho g + f \quad (2)$$

2. Solving for the discrete phase (solids) and specifying appropriate contact models using DEM approach. The DEM calculates normal and tangential velocities using the Newton's law of motion [2].

$$\frac{\partial \vec{u}}{\partial t} = \frac{\vec{f}_{mech} + \vec{f}_{fluid}}{m} + \vec{g} \quad (3)$$

($\vec{f}_{fluid}$ - solved by CFD)

$$\frac{\partial \vec{\omega}}{\partial x} = \frac{\vec{M}}{I} \quad (4)$$

A non-linear hertzian model **(fig 2)** is used calculates the contact force due to overlap between two particles as follows[3];

$$f_{mech} = -q x^{0.25}\frac{dx}{dt} + k x^{1.5} \quad (5)$$

3. Coupling the CFD solution with DEM **(shown in fig 3)**

Proposed Methods

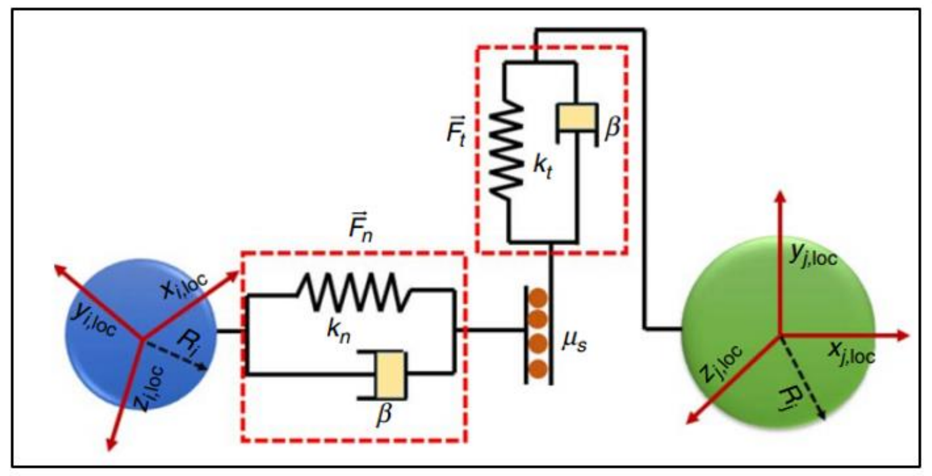


Figure 2. Schematic of the Contact Model

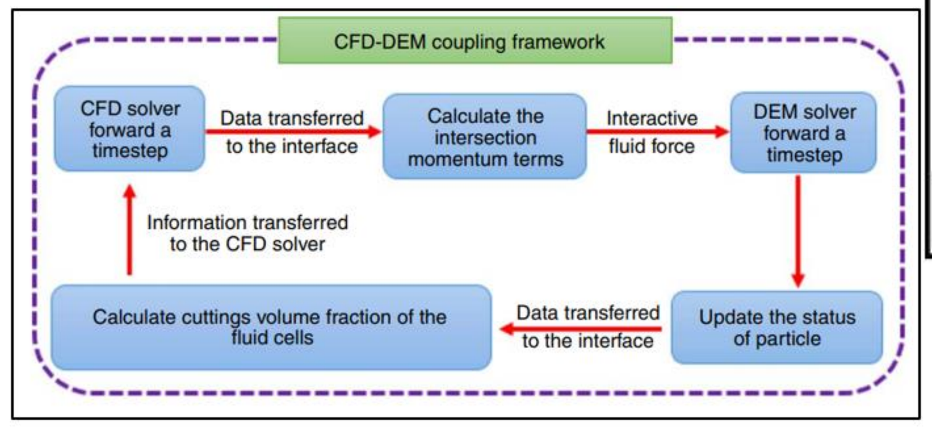


Figure 2. CFD-DEM Coupling calculation process

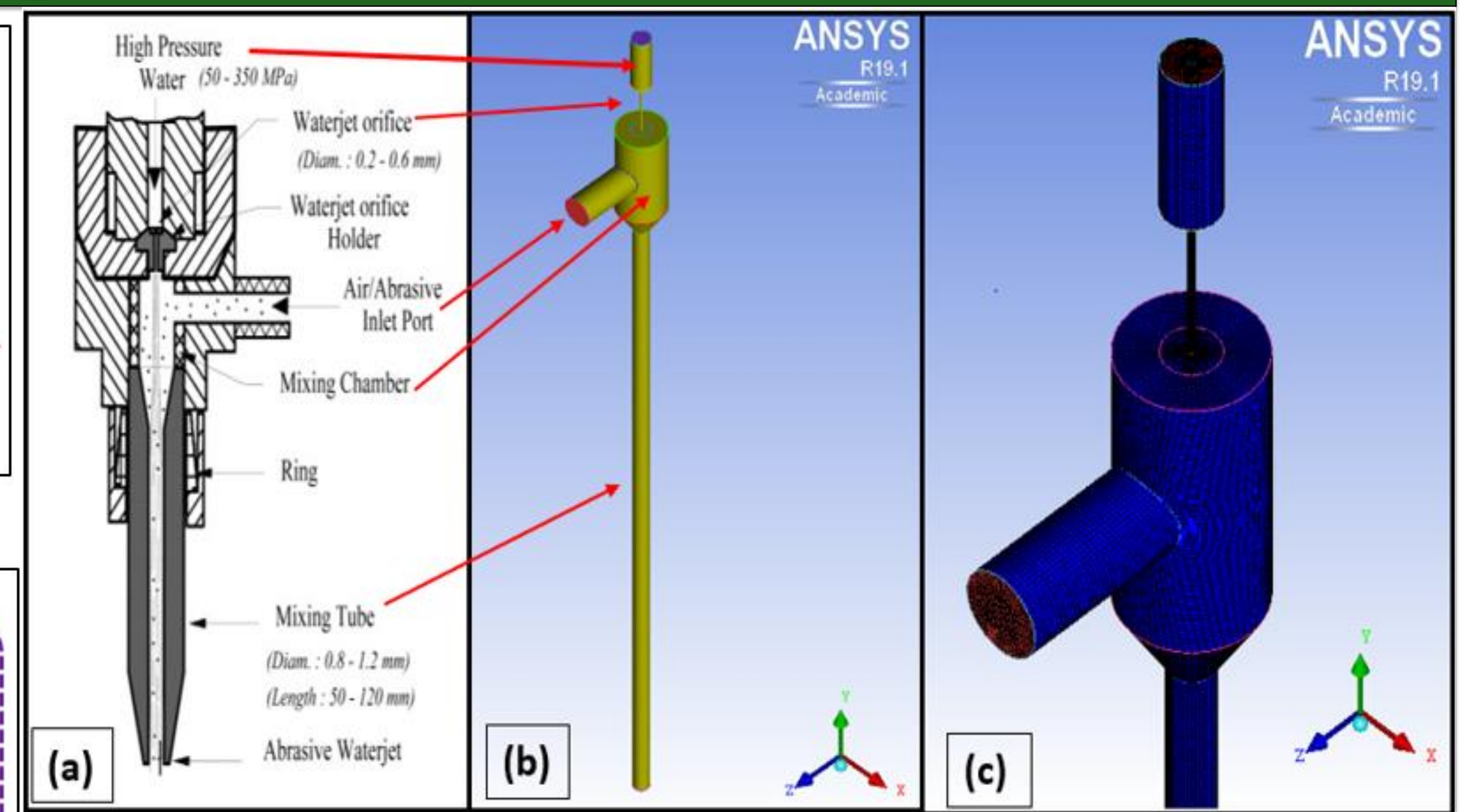


Figure 4 schematics of the (a) geometry of the cutting head (b) 3D computational model created in ANSYS Workbench software (c) Hexahedral mesh created in ICEM-CFD Mesh software.

Preliminary Results (CFD Model)

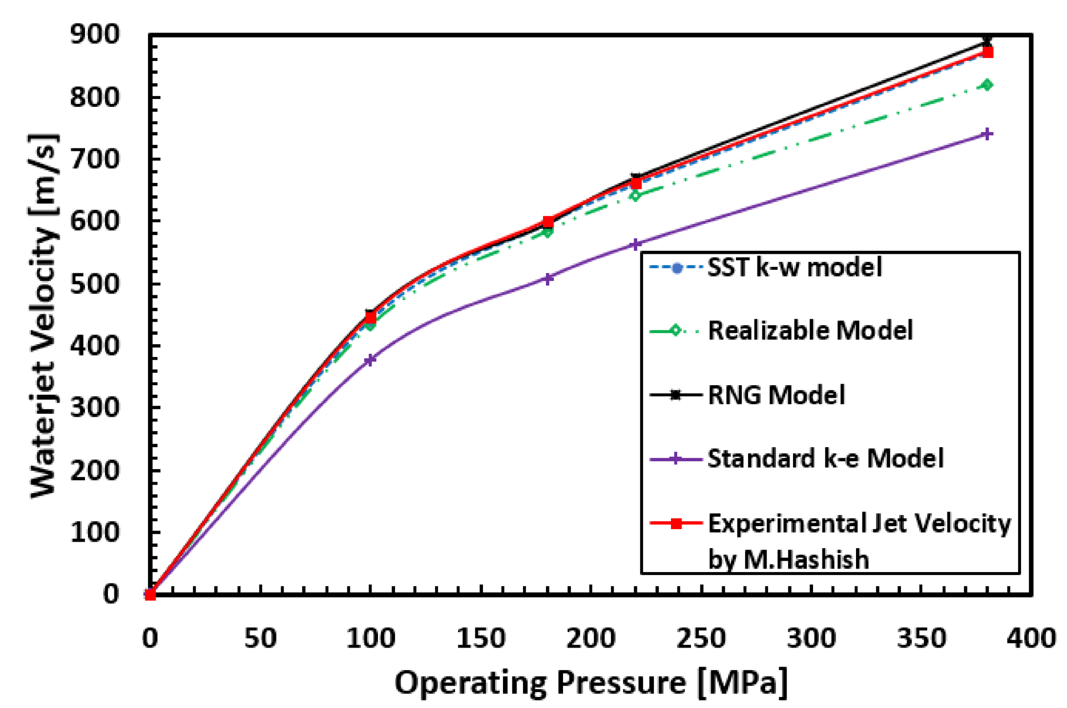


Fig 5. predicted Jet velocity with experimental data of [4]

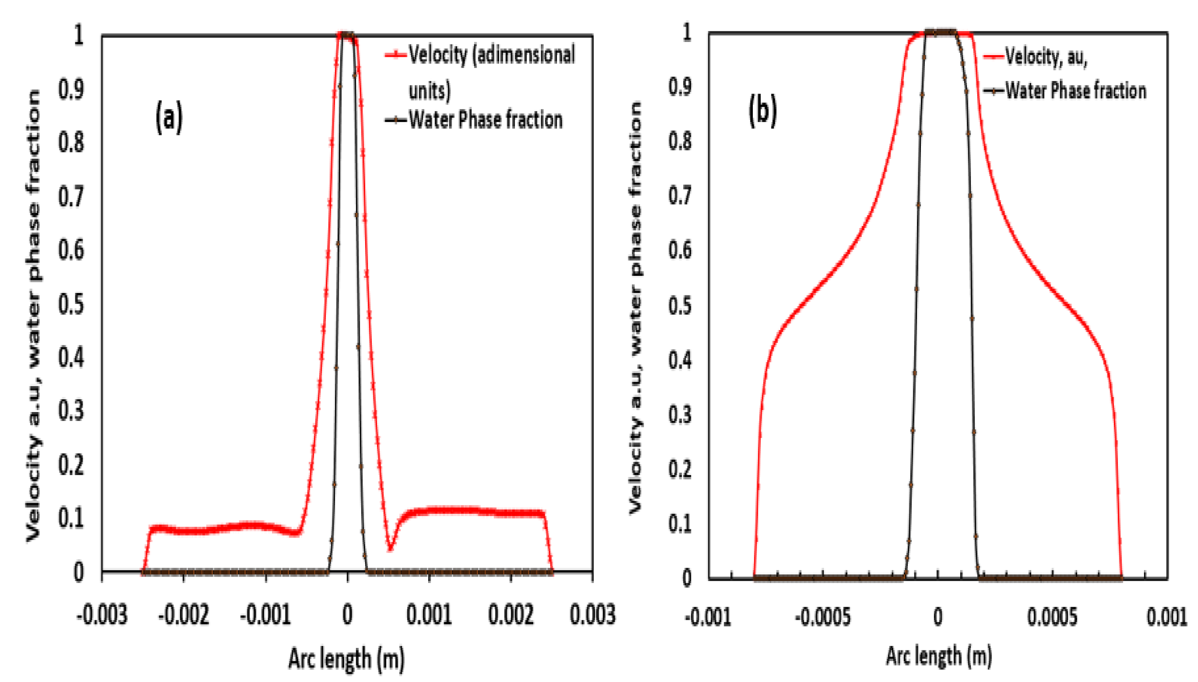


Fig 6. Stabilized jet velocity & Volume fraction profiles in the (a)mixing chamber (b) focus tube

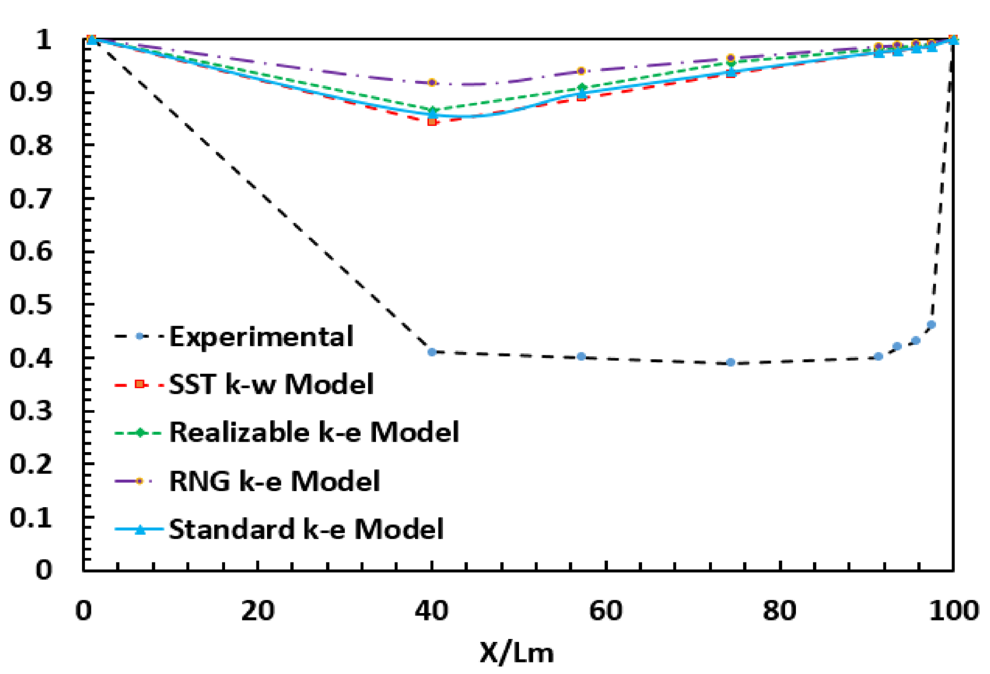
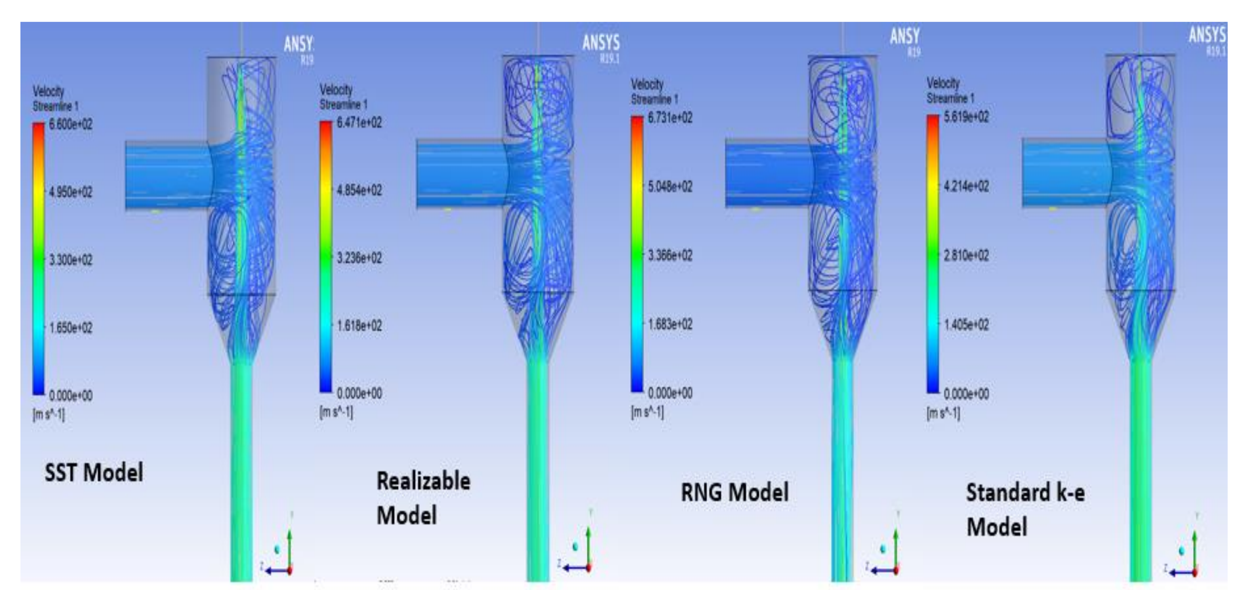


Fig 6. Predicted static pressure with experimental data of [5]



Air Velocity streamlines from the air/abrasive inlet. Operating pressure 220 MPa

Conclusions

- From the CFD model, It was found that SST k–ω, the RNG k–ε, the Realizable k–ε models clearly performed better than Standard k–ε model in predicting the mean velocity profiles.
- It was also revealed that all models produce very similar shaped contour profile of static pressure distribution and the results slightly matched to that of the experimental data.
- The findings of the CFD Model can serve as a general and partial guideline to the choice of turbulence models for those professionals in industry that use numerical codes with built-in turbulence models.

Future work

- Develop DEM model and test different contact models.
- Couple CFD with DEM code.
- Conduct grinding tests to validate the Coupled CFD-DEM model.

References

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