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Experimental and Numerical Investigation of Particle Erosion on Squared T-Junctions

F. L. M. Reis, C. M. P. Rosero, E. R. David, D. A. Rodrigues and A. P. Silva Freire
Mechanical Engineering Program (PEM/COPPE/UFRJ)
21941-972, Rio de Janeiro, Brazil
atila@mecanica.coppe.ufrj.br,

Abstract - The work describes solid particle erosion in a T-junction. Experiments are carried out for two different Reynolds numbers and two typical particle distributions. The work discusses flows with small and large particle load (0.05 to 3% w/w). Global and local (PIV) measurements characterize the properties of the continuous and discrete phases and the amount of eroded surface. The T-junctions were manufactured with stainless steel and aluminium.

***Keywords*:** particle erosion – T-junction – PIV– SST-ω-model.

1. Introduction

Solid particles immersed in gas or liquid streams are a common occurrence in industry. Typical associated problems due to the presence of particles in a flow include alterations in pressure drop, equipment blockage and erosion. The present work discusses sand erosion in a squared "T-junction" (Fig. 1). This geometry is of great relevance for engineering applications but is not often addressed in the literature. Most studies on T-junction deal with single-phase flows in the laminar regime in small or micro-scales arrangements. In large scales, studies are normally dedicated to the description of impinging jets, pipes and elbows.

In the present work, water loaded with sand particles is made to flow through a T-junction at two Reynolds numbers and two typical particle distributions. PIV measurements are used characterize the properties of the continuous and discrete phases. The experiments employ large concentrations of particles (up to 3% w/w) and are performed over very large durations, of typically 32 hours. The extreme conditions of the experiments permitted the tracking of catastrophic events, with severe surface damage and slurry leakages. The work compares accelerated life tests (very high sand concentration tests) with low concentration tests and CFD results so assess how well current erosion models can predict erosion damage.

Slurry flows in T-junctions have been modelled in the past through 3D computational fluid dynamics models via Eulerian-Eulerian or Eulerian-Lagrangian approaches. Here, surface erosion is predicted with the help of an Eulerian-Lagrangian approach and the erosion models of Finnie [1], Oka and Yoshida [2], Zhang et al. [3] and Arabnejad et al. [4].

The work shows that the side walls of the T-junction are particularly sensitive to particle erosion. The bottom impinging wall benefits from particles that bounce back and on hitting new arriving particles reduce the erosion rate. The implication is that the two side walls exhibit the most serious erosion damage whereas the area that faces the main impinging flow shows nearly no erosion. This phenomenon had previously been noted by other authors (Zhang et al. [5]). The present CFD simulations are shown to predict well the erosion rates on the side and bottom walls. Erosion ratio is the loss of mass surface caused by the mass of particles impacting on the surface.

2. Experimental Facility

The general flow geometry is shown in Fig. 1. Sand particles with an average 150 μm diameter and in a concentration of 0.5 to 3% (w/w) are dispersed in flows with $R_e = 1.0 \times 10^5$ and 1.6×10^5. The surface materials are stainless steel AISI 314 and aluminium.

3. Numerical Simulations

To numerically simulate the erosion, an Eulerian-Lagrangian approach is used to evaluate the two-phase flow (liquid and solid). Velocity and pressure fields of the liquid phase are evaluated through the conservation equations, closed with the k-□-SST and realisable k-□ turbulence models. The particles are modelled through a one-way coupling Lagrangian approach. Forces acting on the particles include weight, buoyancy, non-spherical drag force, Saffman-Mei lift force and virtual-mass. The coefficient of restitution of the particles are determined through the formulation of Grant e Tabakoff [6]. Grid meshes consisted of $5x10^5$ to $2x10^6$ cells so that near a wall the condition $y^+ < 1$ was granted. Typically $5x10^6$ particles were considered to impact on the wall to provoke surface erosion. These particles were given a stochastic distribution over the incoming flow cross section.

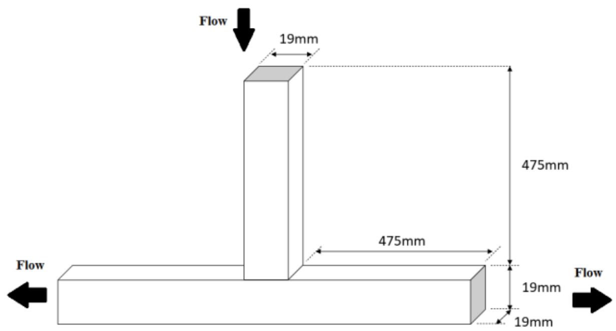

Figure 1. Flow geometry.

4. Results and Discussion

A comparison between the experimental and numerical predictions for the mean velocity and turbulent kinetic energy profiles is shown in Figs. 2 and 3 for $R_e = 1.6x10^5$. The general agreement of the mean velocity profile for both the SST and the k-ε models is good. Predictions for the peak value of k at position x = 2L are good for the k-ε model.

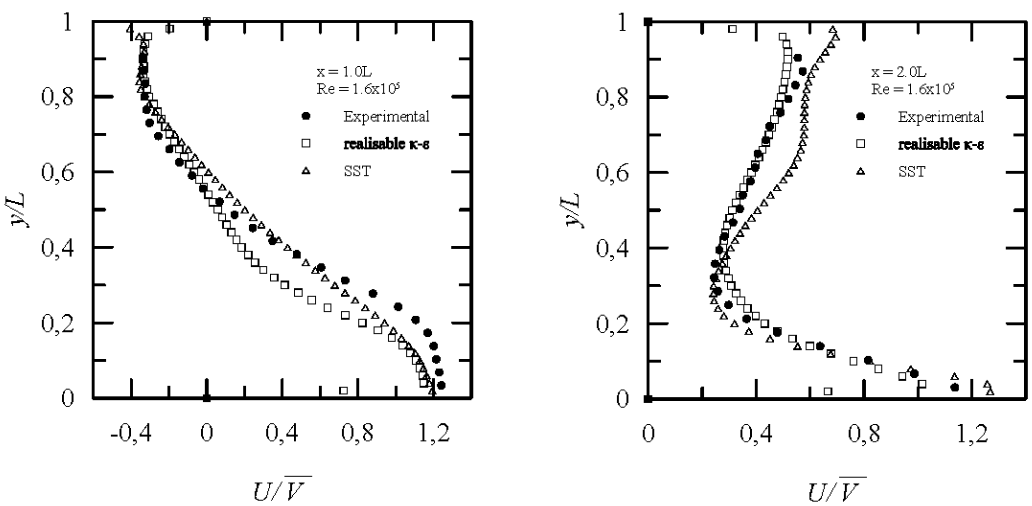

Figure 2. Mean velocity profiles at positions x = 1L, 2L, L = height of cross section, for $R_e = 1.6x10^5$.

The general erosion imprint in the bottom wall is shown in Fig. 4 for both the actual eroded surface and the numerical simulations.

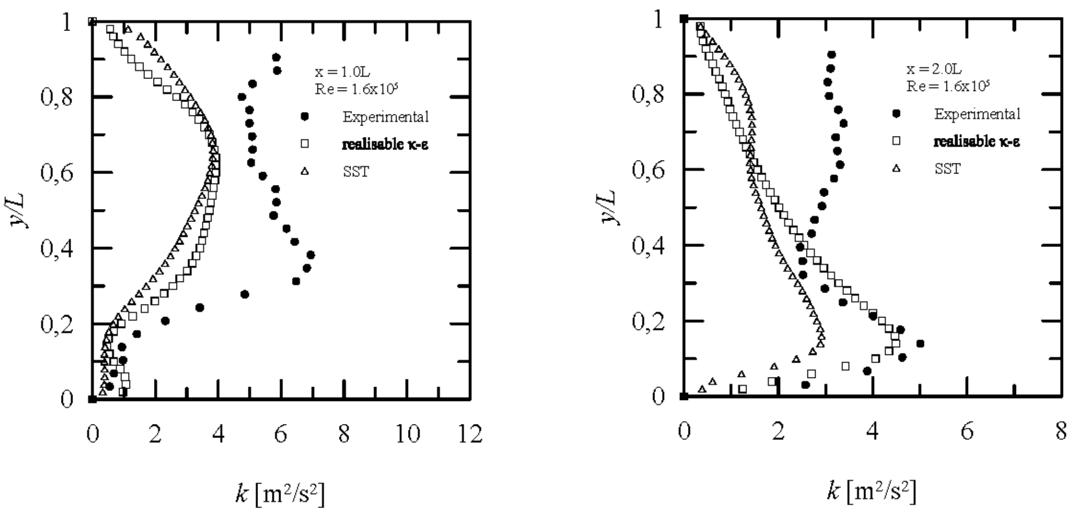

Figure 3. Turbulent kinetic energy profiles at positions x = 1L, 2L, L = height of cross section, for $R_e = 1.6x10^5$.

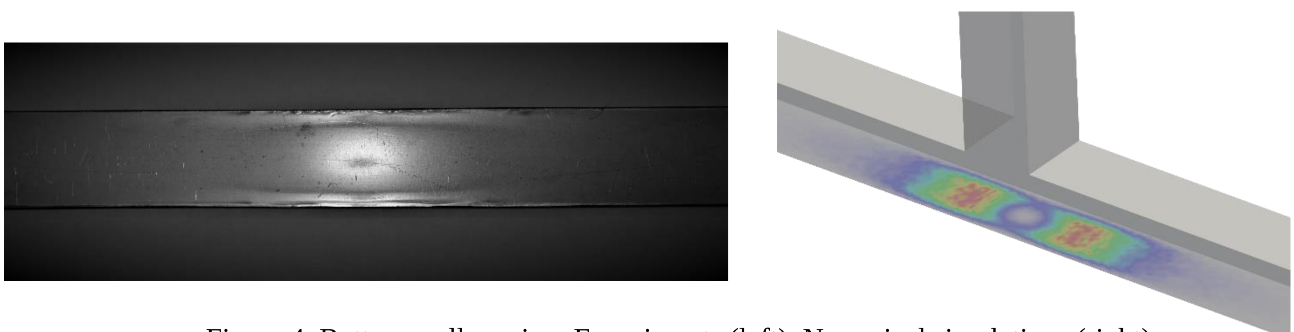

Figure 4. Bottom wall erosion. Experiments (left). Numerical simulations (right).

Profiles of the three eroded surfaces according with the models of Finnie [1], Oka and Yoshida [2], Zhang et al. [3] and Arabnejad et al. [4] are shown in Fig. 5a. An evident result is that the k-□ model tends to furnish lower predictions of eroded material when compared to the SST model.

The Oka and Yoshida [2] and Arabnejad et al. [4] models exhibit similar behaviour and tend to predict more severe erosion than the Zhang et al. [3] model. The results provided by a combination of the SST-Arabnejad (or SST-Oka model) tended to yield the best fit to the experimental data (Fig. 5b).

Conclusion

The above text has illustrated some of the obtained results on erosion in a "T" geometry in experiments that employ large concentrations of particles. Further results including graphs that depict large catastrophic events, with severe surface damage and slurry leakages, are to be shown in the oral presentation. Samples of eroded surface are also to be exhibited.

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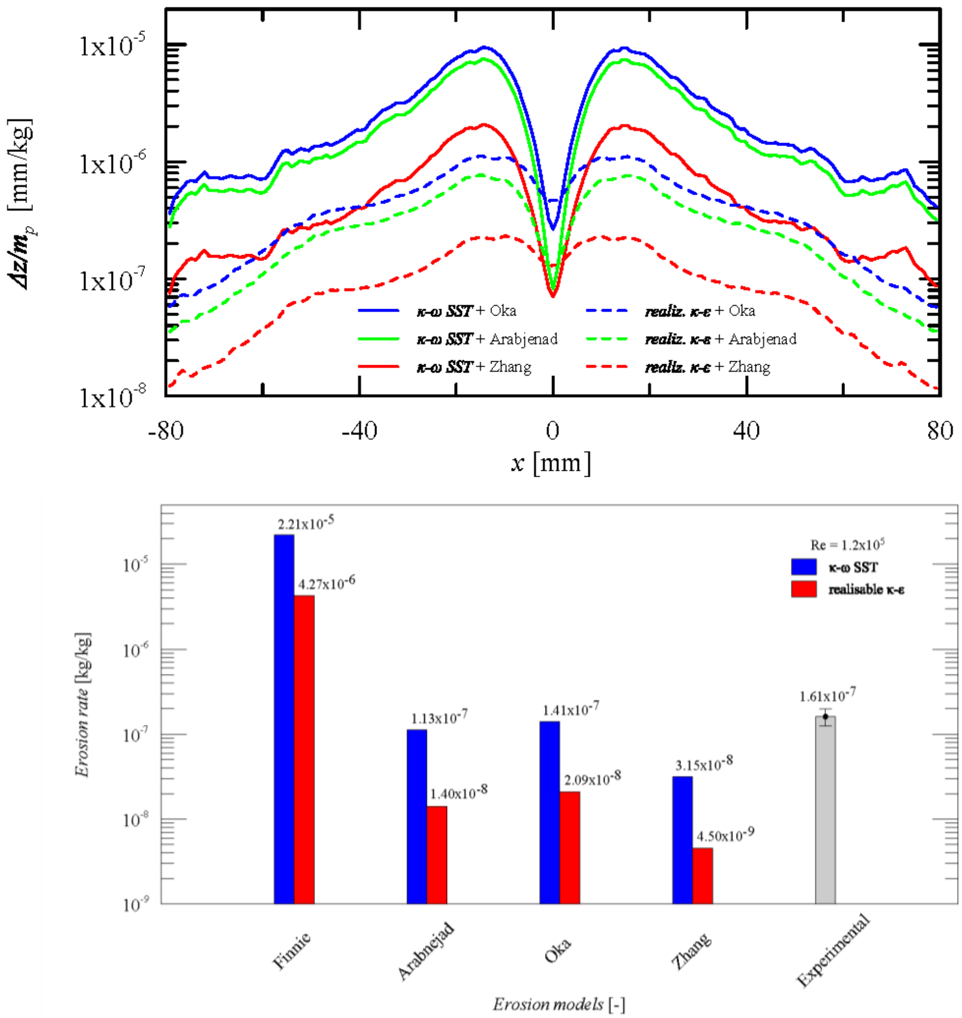

Figure 5. Eroded surface according to the models of Oka and Yoshida (2005), Zhang et al. (2007) and Arabnejad et al. (2015).

References

[1] I. Finnie, "Erosion of surfaces by solid particles", *Wear*, vol. 3, pp. 87—103, 1960.

[2] Y.I. Oka and T. Yoshida, "Practical estimation of erosion damage caused by solid particle impact: Part 2: Mechanical properties of materials directly associated with erosion damage", *Wear*, vol. 259, 1-6, pp. 102—109, 2005.

[3] Y. Zhang, E. Reuterfors and B.S. McLaury, "Comparison of computed and measured particle velocities and erosion in water and air flows", *Wear*, vol. 263:1-6, pp. 330—338, 2007.

[4] H. Arabnejad, A. Mansouri and S. Shirazi, "Development of mechanistic erosion equation for solid particles", *Wear*, vol. 332, pp. 1044-1050, 2015.

[5] J.X. Zhang, Y.Q. Bai, J. Kang and X. Wu, "Failure analysis and erosion prediction of tee junction in fracturing operation. J. of Loss Prevention in the Process Industries", vol. 46, pp. 94—107, 2017.

[6] G. Grant and W. Tabakoff, "Erosion prediction in turbomachinery resulting from environmental solid particles", *J. of Aircraft*, vol. 12, pp. 471—478, 1975.