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Modeling of Gas-Particle Flows
Applications to Safety Studies in ITER Fusion Reactor

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ABSTRACT

If the vacuum vessel (VV) of the fusion reactor ITER breaks, air may flow inside the VV through the breaches, leading to a Loss-Of-VAcuum event (LOVA). Simulating accurately such a pressurisation is important since it may lead to dust explosion in the VV. Indeed, during the life of the plasma, dust (beryllium, graphite) is accumulated at the bottom of the vacuum chamber. In the case of air leaks, strong expansion waves and shock wave structures will be generated and will interact with the deposited dust, mobilizing it into the atmosphere leading to a likely explosion. The simulation of this scenario is a challenge for today numerical methods and models. The geometry of the chamber is three dimensional and of large dimensions. This study therefore requires computational ressources that can be only found on large parallel platforms. Moreover, the chamber is initially near vacuum and the simulation of its pressurization by an accidental air entry requires robust numerical methods able to compute near vacuum flows that will occur in a large Mach number range from highly supersonic to nearly incompressible ones.

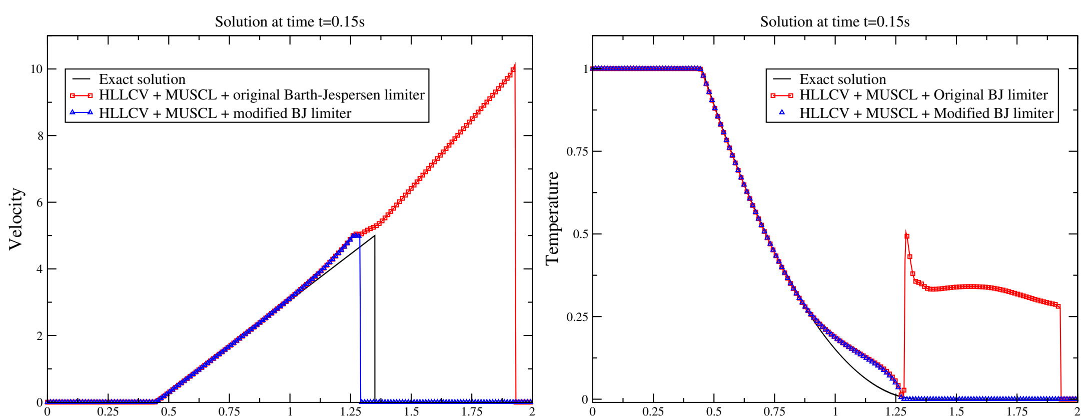

Figure 1: Vacuum shock tube problem with 500 points in the x-direction. Comparison between the original method (red squares) and the modified one (blue triangles).

The present work introduces a gas-particule model in which the gas phase is classically treated using

Euler equations while the solid phase is modeled as a pressureless gas [1,2].
This work will firstly tackle the difficulty to compute very low density gas flows [3]. We will show that classical methods fail to provide accurate solutions to this problem. More specifically, the localisation of the gas-vacuum interface is incorrect, particularly when second-order space accurate schemes are used. We will show how to circumvent this issue and capture the vacuum-front accurately.
Secondly, a numerical approach to approximate the pressureless gas system will be described [4]. The scheme uses Godunov-type method taking into account the occurence of delta-waves.

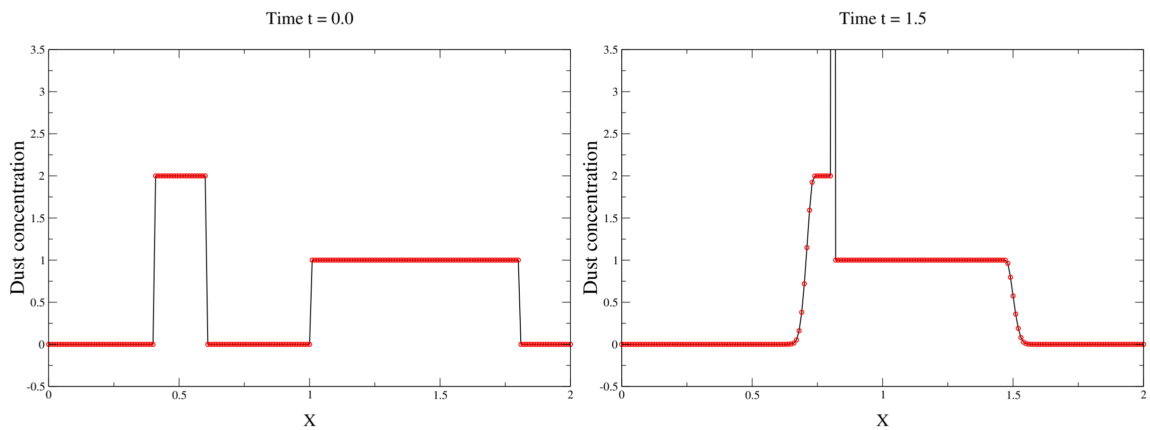

Figure 2: Numerical solution of collision between two finite dusty clouds at time: $t = 0$ and $t = 1.5$.

Thirdly, the numerical treatment of the interaction terms coupling both phases will be detailed. Since the resulting ODE system describing theses interactions between phases can be stiff, robust implicit time integration schemes of Rosenbrock type are used [5].
Numerical test-cases used to validate the whole numerical framework will be presented. For instance, Figure 1 illustrates the improvement in the localisation of the gas-vacuum interface produced by the newly proposed scheme while Figure 2 presents the results of the collision between two finite dusty clouds and illustrates the occurence of delta-shock [6]. Finally, this presentation will conclude by the application of this numerical method to the safety studies of LOVA event in the future fusion reactor ITER [7].

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