Numerical Analysis of Rocket Exhaust Cratering

2007 Center Director's Discretionary Fund Project

Lunar Launch/ Landing Site Ejecta Mitigation

Supersonic jet exhaust impinging onto a flat surface is a fundamental flow encountered in space or with a missile launch vehicle system. The flow is important because it can endanger launch operations. The purpose of this study is to evaluate the effect of a landing rocket's exhaust on soils. From numerical simulations and analysis, we developed characteristic expressions and curves, which we can use, along with rocket nozzle performance, to predict cratering effects during a soft-soil landing.

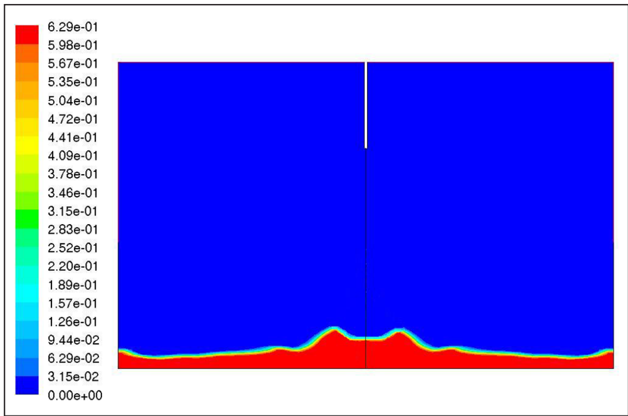
We conducted a series of multiphase flow simulations with two phases: exhaust gas and sand particles. The gas expanded from the nozzle exit with a prescribed velocity profile and impinged onto the sand surface. The interaction between those two phases formed the erosion on the sand bed. The results enabled use to describe the basic effects of gas jets impinging on sand and to relate crater dimensions to the soil characteristics and the numerical simulation parameters, including volume fraction, packing limit, and angle of internal friction.

The main objective of the simulation was to obtain the numerical results as close to the experimental results as possible. After several simulating test runs, the results showed that packing limit and the angle of internal friction are the two critical and dominant factors in the simulations. Our work included

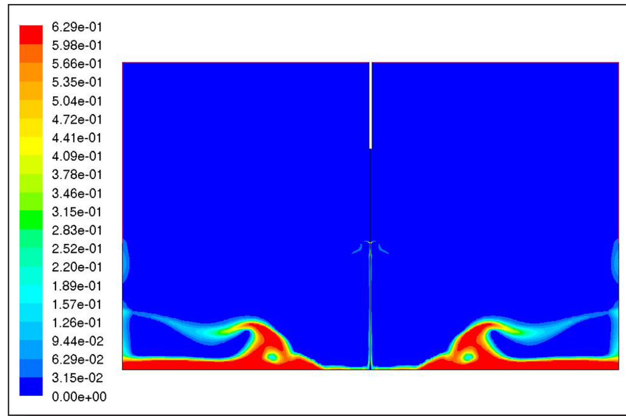
- reviewing numerical and experimental studies related to multiphase, supersonic flow,
- performing axisymmetric and 3-D supersonic flow impingement,
- comparing two-phase flow numerical results with experimental data,
- implementing a new user-defined function to model the nozzle boundary condition,
- presenting the study at the AIAA Fluid Dynamics conference, and
- delivering validated numerical solutions with a final report.

Contact: Dr. Bruce T. Vu <Bruce.T.Vu@nasa.gov>, NASA-KSC, (321) 867-2376

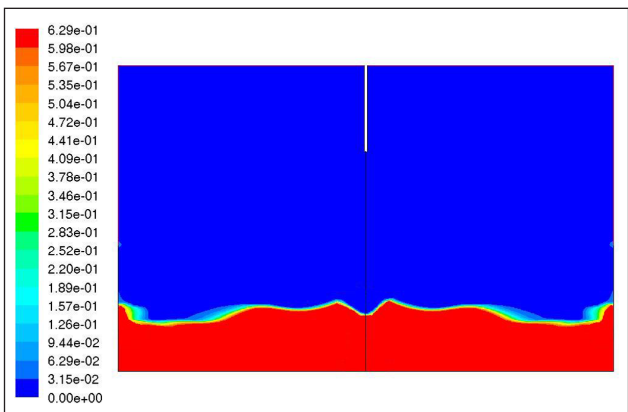
Participating Organization: Florida Institute of Technology (Dr. Pei-feng Hsu)



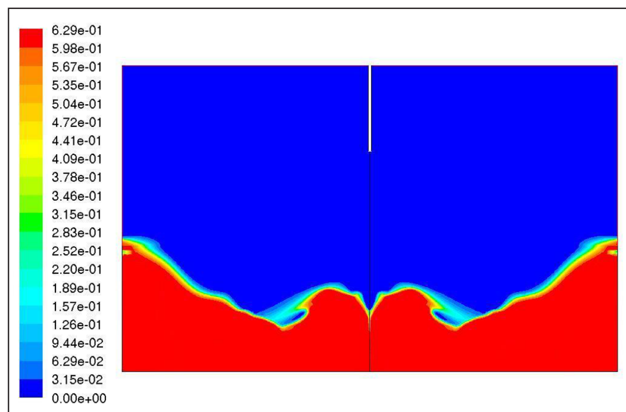
Sand volume fraction contour at t = 0.5 s Packing limit is 0.63.



Sand volume fraction contour at t = 1.0 s Packing limit is 0.63.



Sand volume fraction contour at t = 0.5 s Packing limit is 0.7.



Sand volume fraction contour at t = 1.0 s Packing limit is 0.7.