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Title: The Sedov Test Problem

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Intended for: Online Vault

The Sedov Test Problem

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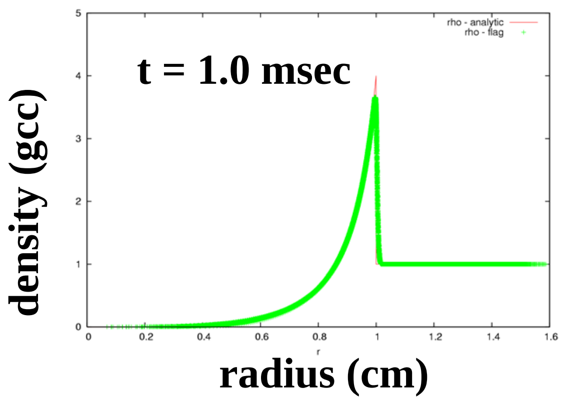
The Sedov test is classically defined as a point blast problem.

- A self-similar solution was independently derived by von Neumann (1941), Taylor (1941), and Sedov (1945)

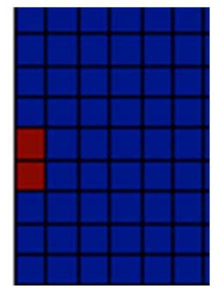
$$R = \left(\frac{E}{\kappa \rho_0}\right)^{1/5} t^{2/5}$$

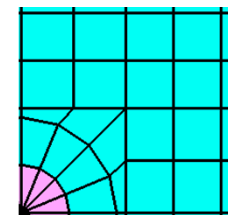
- Here, an energetic cell is initialized in a gamma-law gas (g=5/3, r=1.0 gcc).
- For most calculations here, the problem domain is 1.125cm x 2.25cm over a 91x46 mesh (so the initial cell energy is 493.59 MJ), leading to a shock position of 1.0 cm at 1.0 msec



1. von Neumann J (1941) The point source solution. NDRC Division B Rept AM-9. Reprinted in (1963) Taub AH (ed) John von Neumann collected works. Pergamon, Oxford, pp 219-237
2. Taylor GI (1941) The formation of a blast wave by a very intense explosion. Brit Rept RC-210. Reprinted in (1950) Proc Roy Soc A 186:159
3. Sedov, L. I., Appl. Math. Meth, 9(4), pp. 294, 1945.
4. Korobeilnikov, V.P., Mel'nikova, N.S., & Ryazanov, Ye.V., Teoriya Tochechnogo Vzryva, FizMatLit, Leningrad, 1961. [Transl.: The theory of point explosion, JPRS 14, 334, U.S. Dept. of Commerce, Washington, DC, 1962], Chap. 2

The Sedov problem has led us to advances in algorithms and in their understanding

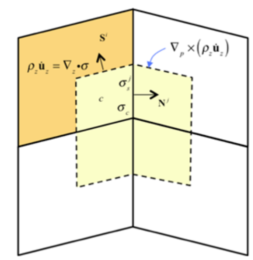




- What problem are we really computing?
  - Point source versus finite-volumetric source
  - Spherical source versus cylindrical source
- Results indicate reasonable shock capture.
- Observations of vorticity generation have driven this work.
- Errors include discretization, remap, and rotational equilibrium.
  - Current and future work includes CCH developments and treatments for artificial viscosity or the underlying discretization.

Vorticity generation can be physical or numerical. Both play a role in Sedov calculations.

- Physically, a non-spherical source will lead to symmetry breaking and vorticity generation. The mechanism is through the baroclinic source.
- Numerically, vorticity can be produced through the discretization itself, or through the application of artificial viscosity or hourglass treatments.
- Numerically, vorticity can be damped through numerical dissipation.



Burton's talk

$$\frac{D\vec{\omega}}{Dt} = \frac{\partial\vec{\omega}}{\partial t} + (\vec{V}\cdot\vec{\nabla})\vec{\omega}$$

$$= (\vec{\omega}\cdot\vec{\nabla})\vec{V} - \vec{\omega}(\vec{\nabla}\cdot\vec{V}) + \frac{1}{\rho^2}\vec{\nabla}\rho \times \vec{\nabla}p + \vec{\nabla}\times\left(\frac{\vec{\nabla}\cdot\underline{\underline{\tau}}}{\rho}\right) + \vec{\nabla}\times\vec{B}$$

Time rate of change of vorticity

Baroclinic source

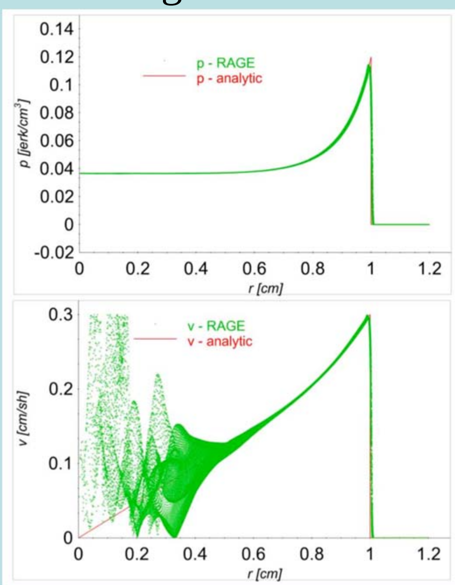
viscous dissipation

The RAGE code (Eulerian) resolves the shock well, but produces vorticity. The source definition matters.

For a **two-zone source**, the shock capture converges with mesh resolution, but vorticity is generated near the source region.

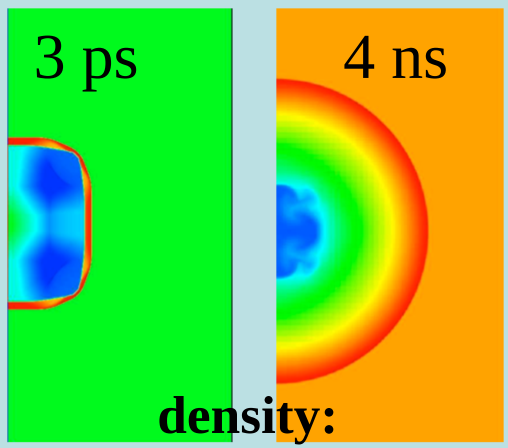
pressure

velocity



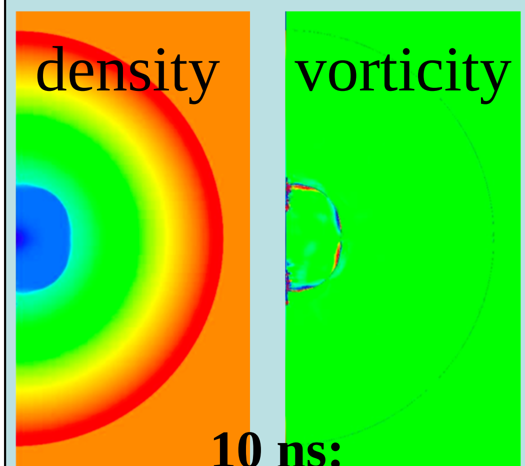
2-zone source

A **high-res simulation of a cylindrical blast** confirms that some vorticity production is expected. Note the late-time formation of a generally spherical shock.



density:
cylindrical blast

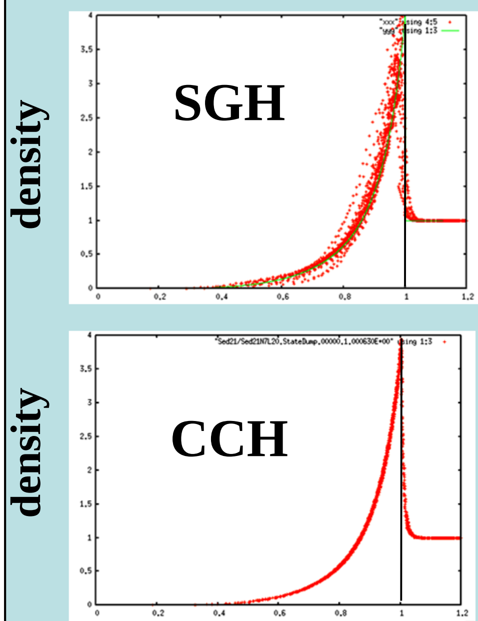
A **high-res simulation of a spherical blast** leads to a reduction in vorticity production. However, the vorticity production mechanism still exists.



10 ns:
spherical blast

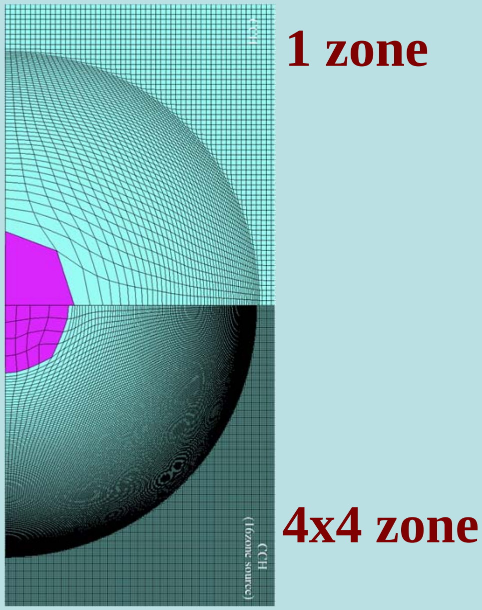
For the FLAG code (Lagrange), CCH is superior to SGH by avoiding spurious vorticity generation.

For a **two-zone source**, SGH with standard settings produces noisy results with vorticity. CCH does not.



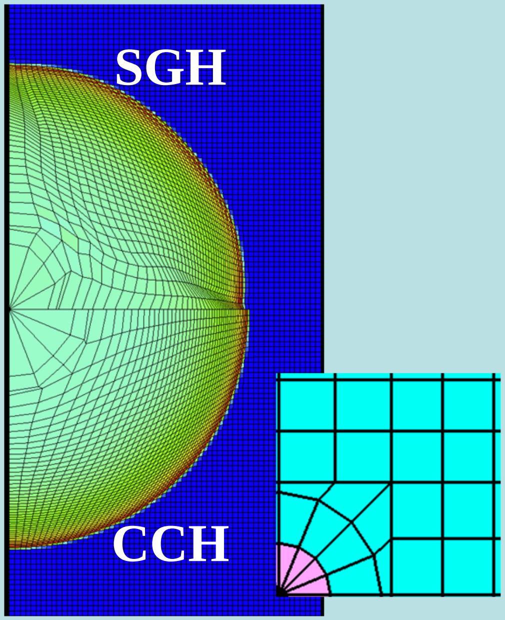
2-zone source

Even with **higher resolution in the source**, results indicate very low vorticity.



1 zone vs 4x4 zone [cylindrical] source

For a **spherical source**, SGH still produces vorticity/jetting. CCH does not.



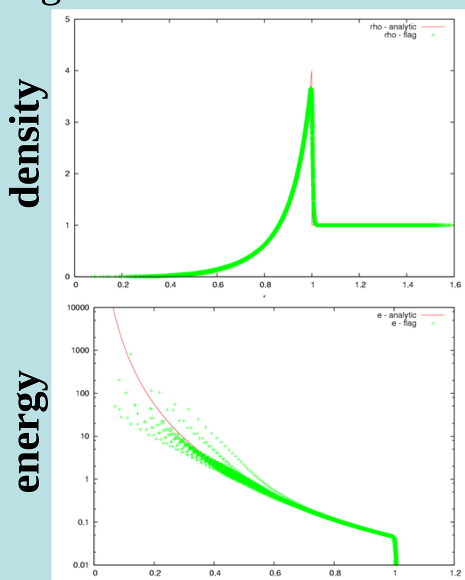
Spherical source

Los Alamos NATIONAL LABORATORY EST. 1943

NNSA

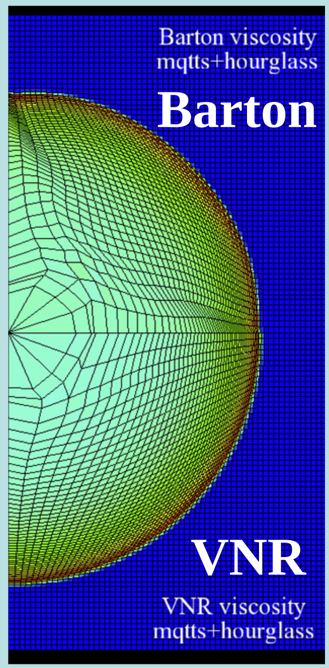
FLAG SGH currently has a number of options that improve results over traditional settings.

Tensor artificial viscosity leads to much more symmetric results for the shock capture, but vorticity remains near the source region.



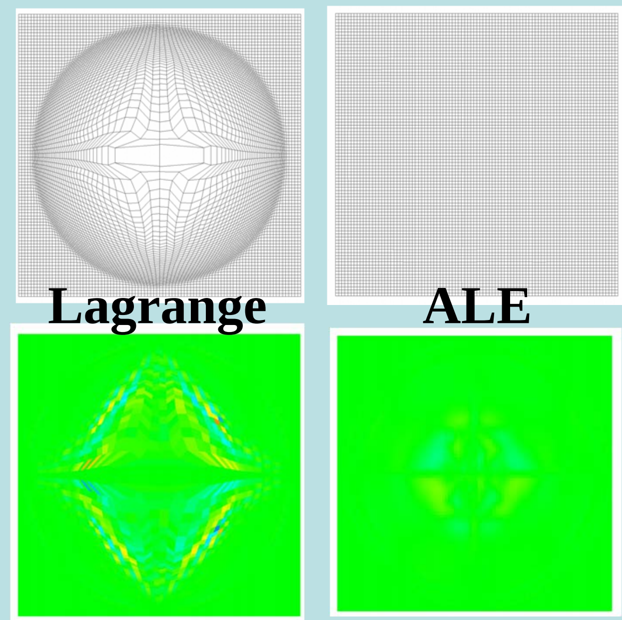
2-zone source

Classical VNR artificial viscosity also avoids spurious vorticity generation.



Spherical source

ALE also leads to reduced vorticity production through numerical dissipation and/or turning off mesh stability models.



2-zone source

Vorticity production, not shock capture, has driven the Sedov work. We are pursuing treatments with respect to the hydro discretization as well as to artificial viscosity.

- Rage: Eulerian
  - The source specification matters!
  - Results are comparable with the FLASH Eulerian code (U. Chicago)
  - Hi-res simulations of cylindrical sources suggest actual (real) vorticity production
  - Hi-res simulations of spherical sources lead to reduced vorticity production
- FLAG: Lagrange CCH
  - Results are superior to SGH in terms of avoiding spurious vorticity
- FLAG: Lagrange/ALE SGH
  - Vorticity production can be reduced by using alternatives for artificial viscosity or ALE
- Questions
  - How much vorticity **should** be produced? How can we tell?
  - Are there other / better test problems involving just vorticity or shocks + vorticity?
    - E.g. cavity flows