Multi-Dimensional Detonation Theory for Application to the Ram Accelerator

presented by

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Presentation Outline

- Review of one-dimensional detonations
  - steady CJ and ZND theory
  - stability limits and unsteady structures
- Applications for multi-dimensional detonations
  - ram accelerator
  - oblique detonation wave engine
- Modeling approaches
  - Simple, Standard criticism: TOO simple, misses the real world!
  - Detailed, Standard criticism: TOO detailed, cannot capture all scales!
- Results
  - Rankine-Hugoniot shock polars
  - curved wall, straight shock: quasi-one-dimensiona irrotational structure

- straight wall, curved shock: two-dimensional rotational structure
- numerical verifications
  * inert flows
  * asymptotic/numerical two-dimensional steady structure
  * one-dimensional steady detonation structure
  * one-dimensional oscillating/galloping detonation
- steady propagation speeds for idealized ram accelerators
- unsteady oblique detonations

- Conclusions

Discussion limited to

- Powers, J. M., 1994, "Oblique Detonations: Theory and Propulsion Applications," to appear in *Combustion in High-Speed Flows*, J. Buckmaster, T. L. Jackson, and A. Kumar, eds., Kluwer Academic Publishers.
- Grismer, M. J., and Powers, J. M., 1994, "Calculations for Steady Propagation of a Generic Ram Accelerator Configuration," to appear in the *Journal of Propulsion and Power*.
- Grismer, M. J., and Powers, J. M., 1992, "Comparisons of Numerical Oblique Detonation Solutions with an Asymptotic Benchmark," *AIAA Journal*, V. 30, pp. 2985-2987.
- Powers, J. M., and Gonthier, K. A., 1992, "Reaction Zone Structure for Strong, Weak Overdriven, and Weak Underdriven Oblique Detonations," *Physics of Fluids A*, V. 4, pp. 2082-2089.
- Powers, J. M., and Stewart, D. S., 1992, "Approximate Solutions for Oblique Detonations in the Hypersonic Limit," *AIAA Journal*, V. 30, pp. 726-736.

many relevant studies by other authors

Conclusions and Comments

- simple models have their virtues in propulsion applications
  - amenable to variety of solution techniques
  - fundamental insights possible
  - exact and asymptotic solutions useful to verify numerical solutions required for more detailed problems
- steady analysis
  - can identify performance bounds for a given configuration
  - determination of flight speed is a 2-D problem
  - flight speed increases with increasing heat release
  - CJ condition not particularly relevant
    * for flight speeds **below** 1-D CJ, a normal detonation runs away from the projectile
    * for flight speeds **above** 1-D CJ, **with and without** force balance far field behavior is a **stable** CJ oblique detonation
- unsteady analysis
  - one-dimensional instability correctly predicted
  - two-dimensional stability boundary, if not the same, then **close** to the one-dimensional stability boundary
- even with one-step kinetics and simple geometry, resolution of chemistry and flow features is somewhat crude