Linear stability analysis of detonation models by direct numerical computations

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Two main theoretical approaches for studying the stability of detonations are linear stability analysis and direct numerical simulation. Linear stability analysis of detonations originates in the work of Erpenbeck [1]. Later, a number of authors followed his work using an alternative method of normal modes and considered different detonation models based on simplified thermodynamics and chemical mechanisms. Using direct numerical simulations, researchers studied detonations with realistic thermochemistry. Because of the nonlinear nature of the underlying equations, it is difficult to extract linear stability information from the results of these studies.

Here, we combine the ideas of linear stability analysis and direct numerical simulation to study the stability of ZND solutions. We transform the governing equations to the reference frame attached to the leading detonation shock. As the non-steady detonation velocity appears explicitly in the transformed governing equations, we employ the shock-evolution equation as in [2] to be able to compute this velocity. Further, we linearize the equations about the ZND solution. The linear perturbations along with the perturbation of the detonation velocity are subsequently computed numerically. The growth rates and frequencies of the perturbations are extracted from the simulation results.

The approach is illustrated with the modified Fickett's detonation analog suggested in [3] that admits instabilities similar to those in the one-dimensional reactive Euler equations. The reactive Euler equations with a one-step chemical mechanism are also considered.

References

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