

Shock Perturbation Decay

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Perturbations along the shock front appear in the form of triple points. A triple point connects the Mach shock, which is the stronger part of the front, to the incident shock, which is the weaker part, as well as the transverse shock. The presence of a triple point introduces discontinuities in both the local Mach number and the shock-front curvature, which then decay as the shock propagates. These perturbations are especially important in Deflagration to Detonation Transition (DDT) where the shock front is strongly disturbed. In such cases, the perturbations on the shock surface influence the flame dynamics and can generate hot spots that promote detonation formation. Despite its fundamental importance, this problem has received little attention in the literature. The objective of the present study is to investigate perturbations on an inert leading shock wave and to quantify their decay rate through numerical simulations, Geometrical Shock Dynamics (GSD) modeling and inert shock experiments.

To investigate the physical mechanisms governing the decay of shock perturbations, we first perform two-dimensional numerical simulations of the Euler equations. In these simulations, perturbations are introduced by placing an obstacle in the path of the propagating shock wave. The numerical approach accurately resolves the shock structures and their interactions, allowing the decay process to be examined in detail. The results show that these perturbations weaken over time, with a decay rate proportional to $1/x$. In parallel, we implement the the Geometrical Shock Dynamics model, which provides a powerful alternative to classical flow solvers by tracking the evolution of the shock front without resolving the full flow field. This approach relies on the geometrical properties of shock propagation according to Whitham's theory. Within a two-dimensional rectangular channel, the shock front is evolved using this framework, as shown in Figure [1]. We find that the shock-shock interactions and the resulting changes in shock strength predicted by Geometrical Shock Dynamics are in good agreement with the Euler simulations, including the same $1/x$ decay behavior. Experimental validation of this scaling law is essential both to confirm its accuracy and improve our understanding of the problem. To this end, inert shock experiments with two triple points along the shock front are conducted in a 3.4 m long narrow shock tube. The evolution and decay of the front are visualized using both shadowgraph and schlieren techniques with a Shimadzu HPV-X2 high-speed camera. Preliminary experimental observations are consistent with the predicted attenuation of the perturbations.

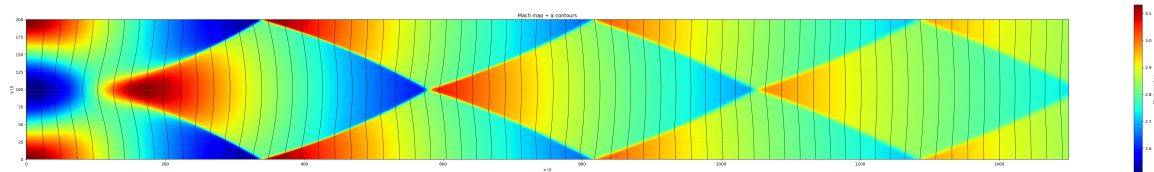


Figure 1: Map of the Mach number of the leading shock and contours of t constant

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