Low-Temperature Shock Tube Ignition Studies in Hydrogen

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Motivation

Recent studies have highlighted the failure of current hydrogen combustion kinetic models to predict experimental shock tube ignition delay times at low-temperature conditions (less than 1000 K). The failure cast doubts on the ability to simulate ignition delay times at these conditions in synthesis gas (syngas), a mixture of hydrogen and carbon monoxide in various compositions. Syngas is being considered as an alternative fuel for combustion applications, such as power-generation gas turbines. A well-developed chemical model for hydrogen at low temperatures is crucial for the proper design of such applications.

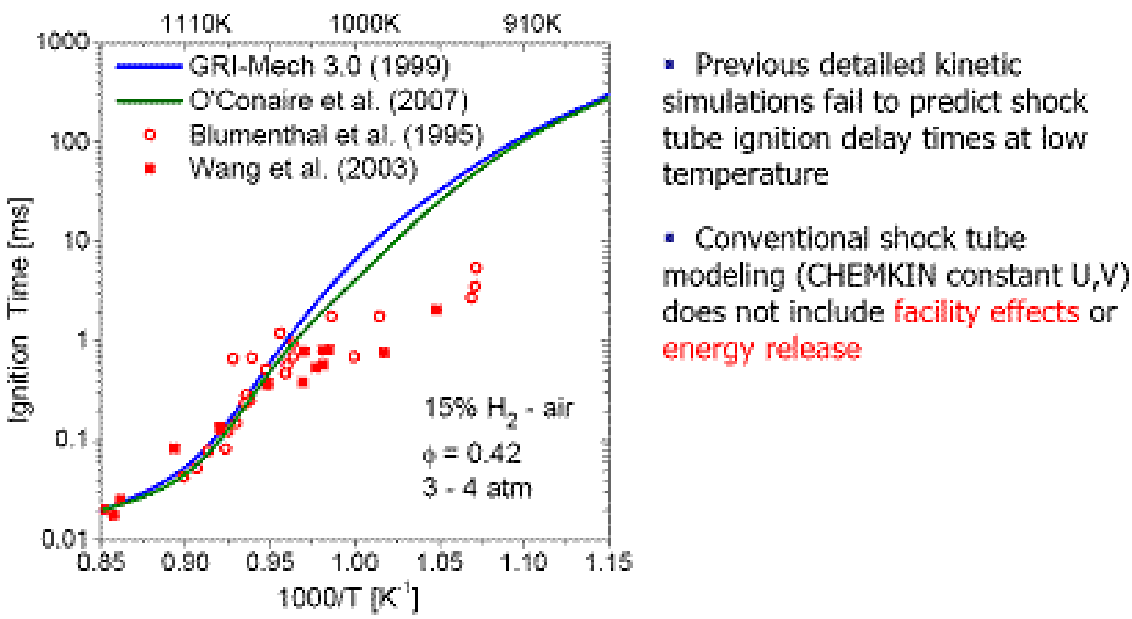

Figure 1: Failure of current kinetic models to predict reflected-shock ignition delay time data

Overview

Our research aims to resolve the discrepancy between experimental low-temperature shock tube hydrogen ignition data with that predicted by current models, by moving away from conventional reflected shock modeling. Our efforts have led us to develop a new thermodynamic-gasdynamic model called CHEMSHOCK to account for the non-ideal effects of facility-dependent effects and localized energy release that are especially prominent at long test time which occur at low temperatures.

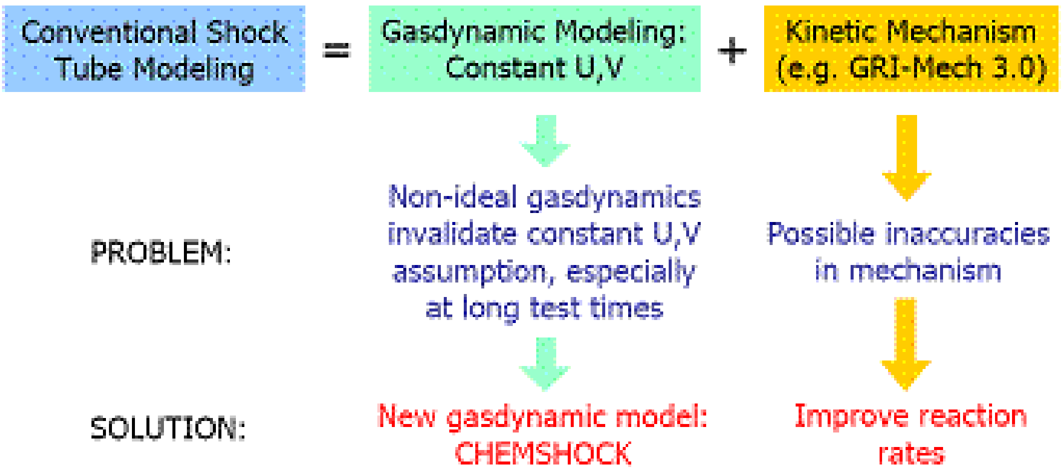

Figure 2: Shock tube modeling flow-chart

With a new gasdynamic model for low-temperature shock tube modeling, we are then able to design experiments to make more accurate measurements of the reaction rates for key reactions in the hydrogen/oxygen kinetic mechanism using the shock tube facilities available in our lab. By making improvements to the kinetic mechanism, we see a better correlation between modeling and experimental shock tube ignition data at low temperatures.

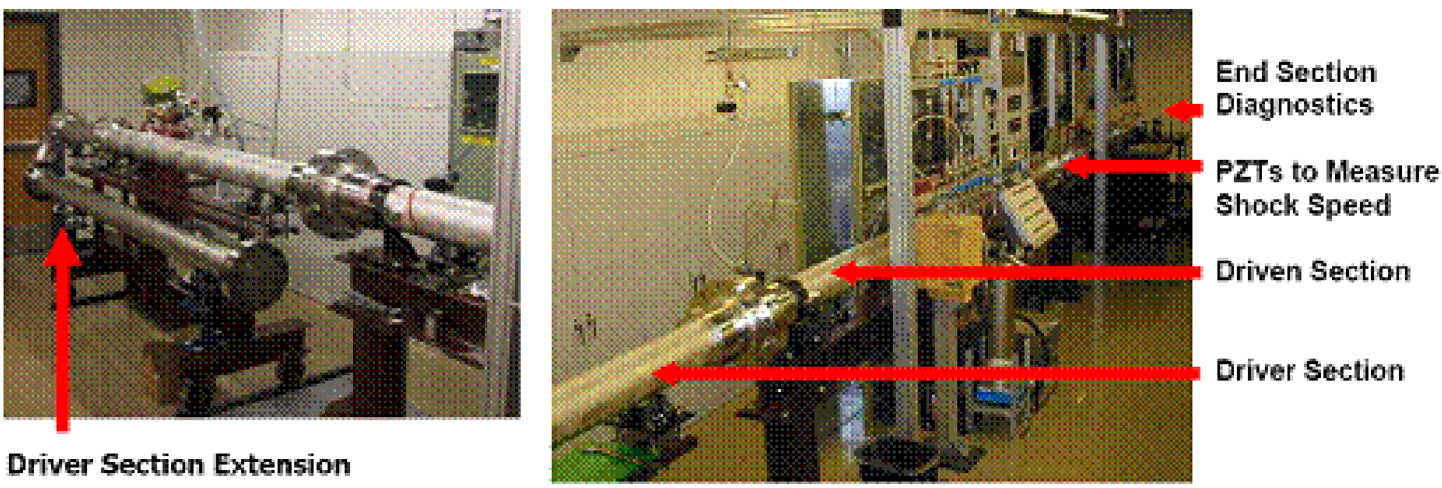

Figure 3: Ultra-high-purity kinetics shock tube facility at Stanford

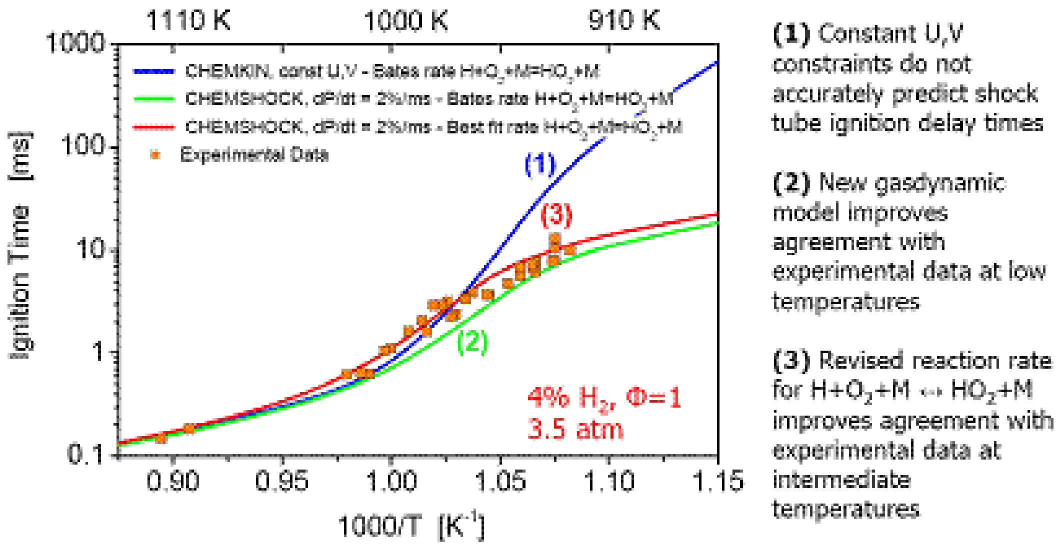

Figure 4: New models better predict experimental ignition delay time data for hydrogen

References

1. H. Li, Z.C.Owens, D.F. Davidson and R.K. Hanson, "A Simple Reactive Gasdynamics Model for the Computation of Gas Temperature and Species Concentrations behind Reflected Shock Waves," Int. J. of Chemical Kinetics, July 2007.
2. G. A. Pang, D. F. Davidson, R. K. Hanson, "Experimental study and modeling of shock tube ignition delay times for hydrogen-oxygen-argon mixtures at low temperatures", Proc. Combust. Inst. Volume 32, Issue 1, 2009, Pages 181-188.