**Compressible Chemically Reacting Flows**

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*Project definition:*

The main aim of this project is to solve steady state behavior of compressible chemically reacting flows by integrating the corresponding governing equations forward in time. The major point that this project would try to address is the stiffness of the governing equation system. Stiffness here refers to the ratio of the largest to the smallest time scales. The inspiration for this problem was derived from Bussing et al.1

*Multiphysics phenomena:*

The different physical phenomena that are addressed in this project are as follows:

* Steady state concentrations of the species that are considered, through the species conservation equation.
* Fluid variables like velocity and pressure in the domain.
* Additionally, the density variation through the domain is considered as well.

The idea is to solve for steady state behavior across a convergent divergent nozzle in the case of the 1D problems and through a step in case of the 2D problem.

*Numerical challenges:*

Compressible chemically reacting flow systems tend to gain their stiffness from the source terms of the species conservation equations. Depending on the magnitude of these sources, rapid temporal and spatial fluctuations can be introduced to the actual physical system. **Figure 1** shows the variation of some species quantity (U1) and some fluid quantity (U2) over real time. The factor that causes the stiffness is the relatively large difference in the slopes of the two quantities.

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| **Figure 1** Real time behavior of a species quantity (U1) and fluid quantity (U2)1 |

In the case considered in this project, wherein only the steady state solution is required, the time history can be modified to remove this stiffness. A generic method proposed in the work by Bussing et al.1, the authors suggest two steps:

* Have the convective and diffusive terms discretized explicitly whereas the species conservation source term implicitly, a variation of a point implicit scheme.
* Make the system have a single normalized time scale using a preconditioning matrix.

It is to be noted here that the time history that is going to be obtained with this method is in no way the right solution to the original set of governing equations, but at steady state solution for both the modified and original systems are same.

Bussing et al.1 has proposed three different approaches to construct the previously mentioned preconditioning matrix, each one more suitable for a different class of problems. Finally, these methods are applied to a variety of 1D problems and one 2D problem.

We would first use the simplest method to construct the preconditioning matrix for a 1D diatomic dissociation problem considering only the forward reaction rate and validate our constructed model with the ones presented by Bussing et al.1 Further, the effects of having an additional backward reaction rate would be investigated. Additionally, these constructed models can be extended to analyze more complex reactions such as -air reaction, 2D domains and better preconditioning methods.

1. Bussing TRA, Murman EM. Finite-volume method for the calculation of compressible chemically reacting flows. *AIAA J*. 1988;26(9):1070-1078. doi:10.2514/3.10013