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V. The Combustion Group

This group conducted five projects. The goals were to improve understanding of the fundamental mechanisms controlling turbulent combustion and to use this knowledge to construct better models for reacting flows. The bases for these studies were a two-dimensional code including heat release and three-dimensional codes that ignore the hydrodynamic effects of chemical reaction.

W. Ashurst used a finite-difference 3D passive scalar code to study the propagation of a premixed flame in three-dimensional turbulence. In this approach, the flame is a zero-thickness interface located on a level surface of a passive scalar whose value is computed from a field equation. The turbulence is forced in order to produce a constant energy flow. Runs were performed on 16^3 grids to allow fast post-processing. Statistics of the curvature indicate that most flame fronts are nearly cylindrical in shape, justifying two-dimensional studies of flame-vortex interactions. It was also shown that out-of-plane strain tends to counteract viscous effects. The existence of vortical cores which interact strongly with the flame front was also demonstrated.

Two studies (C. Rutland and S. Cant) used a modified version of the Rogallo (3D incompressible spectral) code to produce direct simulations of flames propagating in three-dimensional turbulence with a 128^3 grid. This code treats turbulent flames via passive scalars, thereby limiting it to constant density and precluding consideration of the effect of the flame on the turbulent flow. Their purpose was to gather statistics needed to validate and improve models of the Bray-Moss-Libby type for premixed turbulent combustion. Shape factors of the flame front were computed and indicate the predominance of cylindrical flames, in agreement with a result of Ashurst (see above). PDFs of strain rate and curvature on surfaces of constant progress variable (flame surfaces in this formulation) were computed. Rutland and Trouvé studied the effect of curvature and Lewis number on flame structure. Most of the results were not unexpected but provided quantitative data for the first time; an unanticipated finding is that the temperature behind a flame is affected by the local curvature, a result of considerable potential importance in the prediction of pollutant production.

Two projects (D. Haworth and G. Kosály) used a two-dimensional finite difference program which solves the compressible Navier-Stokes equations. This code takes into account heat release, variable temperature and density, and variable transport properties using up to 400^2 gridpoints; it was developed at CTR by T. Poinsot in 1989. D. Haworth wrote a post-processing program to analyze fields produced by this code. The dominant effect of Lewis number on the local flame structure was demonstrated. Quenching induced by inhomogeneities representing imperfect mixing of the gases were investigated in 1D and 2D cases.

The two studies just described were directly comparable and complementary. Many common results were obtained. For example, both studies show that curvature is more important than strain in controlling the local instantaneous reaction rate, but that strain determines the mean reaction rate. PDFs of burnt gases temperature were obtained and reveal large temperature differences when the Lewis number is not equal to unity.

Only one project (G. Kosály, *et al.*) related to diffusion flames. It studied the validity of the flamelet assumption for diffusion flames using 2D direct simulations made with the compressible flow code. Flamelet models assume that the reaction rate as a function of the conserved scalar and scalar dissipation can be computed from laminar flames. It was found that for large Damköhler numbers (small chemical times), this assumption is accurate. For more intense turbulent fields (smaller Damköhler numbers), the relationship is no longer as precise but remains accurate enough to be applied in practical situations; Kosály and Mell intend to continue this investigation. The effect of heat release on these conclusions was examined.

The comparison between 2D variable density and 3D constant density codes for similar situations was an important feature of this workshop. The results obtained from the two codes on certain issues eg., the effects of molecular transport and of thermodiffusive instabilities (Lewis number effects) were quite comparable, justifying the use of the simpler incompressible flow code for many situations. The use of direct simulations to investigate turbulent combustion is practiced at only a few laboratories worldwide and the Summer Program added considerably to the body of results available and contributed to the confidence of the combustion community in the approach; many original and important results were obtained.

The Combustion Group met twice a week; many of the results are direct consequences of the animated and fruitful discussions that took place at these meetings. The participants also enjoyed the opportunity to work together on a daily basis.

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