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IONIZATION EFFECTS IN SDF COMBUSTION CLOUDS

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Abstract

We investigate ionization and dissociation effects formed in combustion clouds of Shock-Dispersed-Fuel (SDF) explosions. Two SDF charges are considered: (i) a 0.5-g spherical PETN booster surrounded by a 1-g spherical shell of TNT ($\rho_0 = 1\, g/cc$), and (ii) a 0.5-g spherical PETN booster surrounded by a 1-g spherical shell of flake Aluminum (Al) powder with a bulk density of $\rho_0 = 0.6\, g/cc$. Detonation of the booster creates an expanding cloud of explosion product gases and hot fuel (Al or TNT). When this fuel mixed with the shock-heated air, it formed a turbulent combustion cloud that consumed the fuel, and liberated additional energy (15 kJ/g for TNT or 31 kJ/g for Al) over and above detonation energy of the booster (6 kJ/g) that created the explosion; see Kuhl & Reichenbach (2009). Characteristic temperatures in such clouds reach 3,000 K to 4,000 K. In the TNT case, expansion of the detonation products (DP) drives a strong shock into the air, which creates an ionized air shell between the shock and the DP interface; characteristic air temperatures reach ~ 1 electron volt (Brode, 1957). In the Al-SDF case, such cloud temperatures are high enough to dissociate diatomic nitrogen entrained into the cloud by turbulent mixing, and to ionize electrons from the Al combustion products. An example of the instantaneous nitrogen atom concentration field in an Al-SDF cloud is depicted in Fig. 1; at this time (0.24 *ms*), concentration peaks at $n_N / n_{N_2} = 19\%$ (based on Gilmore's thermodynamic calculations for equilibrium air). An example of the instantaneous electron concentration field is presented in Fig. 2; at this time (0.24 *ms*), concentration peaks at $n_e / n_{Al} = 2.7\%$ (based on the Saha equation). In both cases, a conductive combustion cloud is formed, thereby creating an effective electric dipole. As this conductive cloud expands, the electric dipole moment changes, and an electric field appears in the domain of the explosion. Electromagnetic field generation by explosions was first described by Kolsky in *Nature* (1954); discussion of the physical mechanisms of the electromagnetic field generation may be found in review articles by Boronin et al. (1990) and Adushkin & Solobiev (2004). Here we investigate such combustion clouds via *ILES* simulations of the turbulent combustion field with our AMR code. In the *42nd ICT Conference* we presented a survey of our adaptive high-resolution methods [5]. A discussion and validation of our gasdynamic model of TNT combustion can be found in [6]; details of our heterogeneous continuum model of Al particle combustion and validation is described in [7]. These tools will be used to investigate ionization and dissociation effects in SDF combustion clouds.

Acknowledgements

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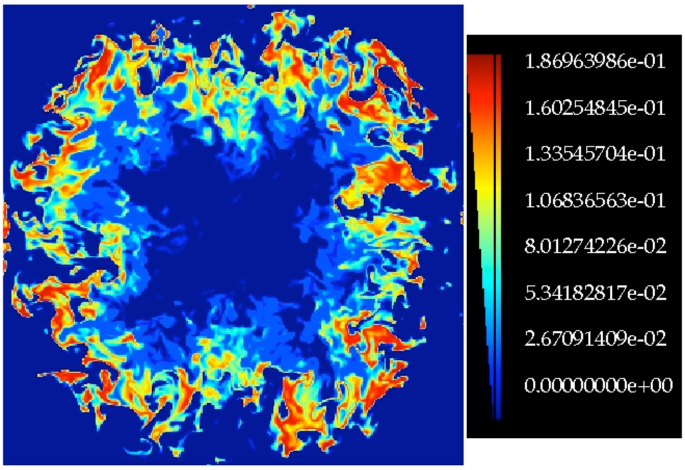

Figure 1. Visualization of the instantaneous nitrogen atom concentration field in the combustion cloud formed by the explosion of an Aluminum SDF charge ($t = 0.239\ ms$); peak concentration is ~19%.

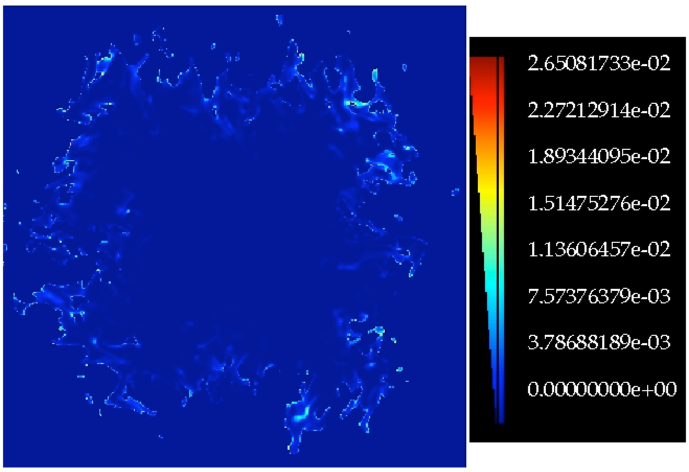

Figure 2. Visualization of the instantaneous electron concentration field in the combustion cloud formed by the explosion of an Aluminum SDF charge ($t = 0.239\ ms$); peak concentration is ~ 2.7%.