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# Reactive Blast Waves from Composite Charges

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# REACTIVE BLAST WAVES FROM COMPOSITE CHARGES

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Investigated here is the performance of composite explosives—measured in terms of the blast wave they drive into the surrounding environment. The composite charge configuration studied here was a spherical booster (1/3 charge mass), surrounded by aluminum (Al) powder (2/3 charge mass) at an initial density of $\rho_0 = 0.604\, g/cc$. The Al powder acts as a fuel but does not detonate—thereby providing an extreme example of a "non-ideal" explosive (where 2/3 of the charge does not detonate). Detonation of the booster charge creates a blast wave that disperses the Al powder and ignites the ensuing Al-air mixture—thereby forming a two-phase combustion cloud embedded in the explosion. Afterburning of the booster detonation products with air also enhances and promotes the Al-air combustion process. Pressure waves from such reactive blast waves have been measured in bomb calorimeter experiments[1],[2]. Here we describe numerical simulations of those experiments. A Heterogeneous Continuum Model[3] was used to model the dispersion and combustion of the Al particle cloud. It combines the gasdynamic conservation laws for the gas phase with a dilute continuum model for the dispersed phase, as formulated by Nigmatulin. Inter-phase mass, momentum and energy exchange are prescribed by phenomenological models of Khasainov. It incorporates a combustion model based on mass conservation laws for fuel, air and products; source/sink terms are treated in the fast-chemistry limit appropriate for such gasdynamic fields, along with a model for mass transfer from the particle phase to the gas. The model takes into account both the afterburning of the detonation products of the booster with air, and the combustion of the Al particles with air. The model equations were integrated by high-order Godunov schemes for both the gas and particle phases. Adaptive Mesh Refinement (AMR) was used to capture the energy-bearing scales of the turbulent flow on the computational grid, and to track/resolve reaction zones. Numerical simulations of the explosion fields from 1.5-g and 10-kg composite charges were performed. Computed pressure histories (red curve) are compared with measured waveforms (black curves) in Fig. 1. Comparison of these results with a waveform for a non-combustion case in nitrogen (blue curve) demonstrates that a reactive blast wave was formed. Cross-sectional views of the temperature field at various times are presented in Fig. 2, which shows that the flow is turbulent. Initially, combustion occurs at the fuel-air interface, and the energy release rate is controlled by the rate of turbulent mixing. Eventually, oxidizer becomes distributed throughout the cloud via ballistic mixing of the particles with air; energy release then occurs in a distributed combustion mode, and Al particle kinetics controls the energy release rate. Details of the Heterogeneous Continuum Model and results of the numerical simulations of composite charge explosions will be described in the paper.

## References

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[2] Kuhl, A. L. and Reichenbach, H. Barometric Calorimeters, *J. Physical Chemistry B*, 2009 (in press).
[3] Kuhl, A. L., Bell, J. B. & Beckner, V. E., Heterogeneous Continuum Model of Aluminum Particle Combustion in Explosions, *Fizika Goreniya I Vzryva* (in press). Abstract Control Number 75278

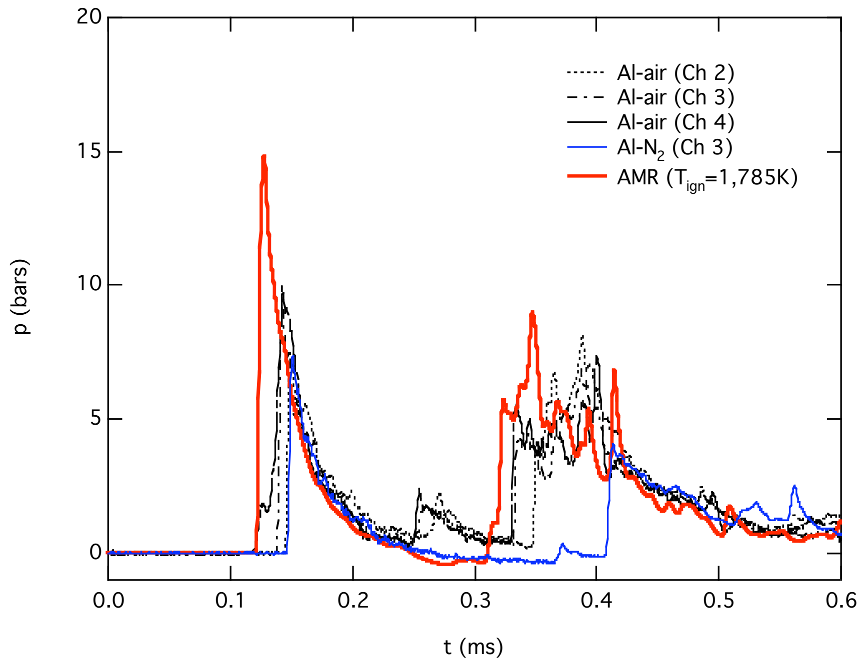


Figure 1. Reflected pressure histories of the reactive blast wave from a 1.5-g Al composite charge ( $R = 15.8\,cm$ ): black curves = experiment in air, red curve = AMR simulation, blue curve = experiment in $N_2$.

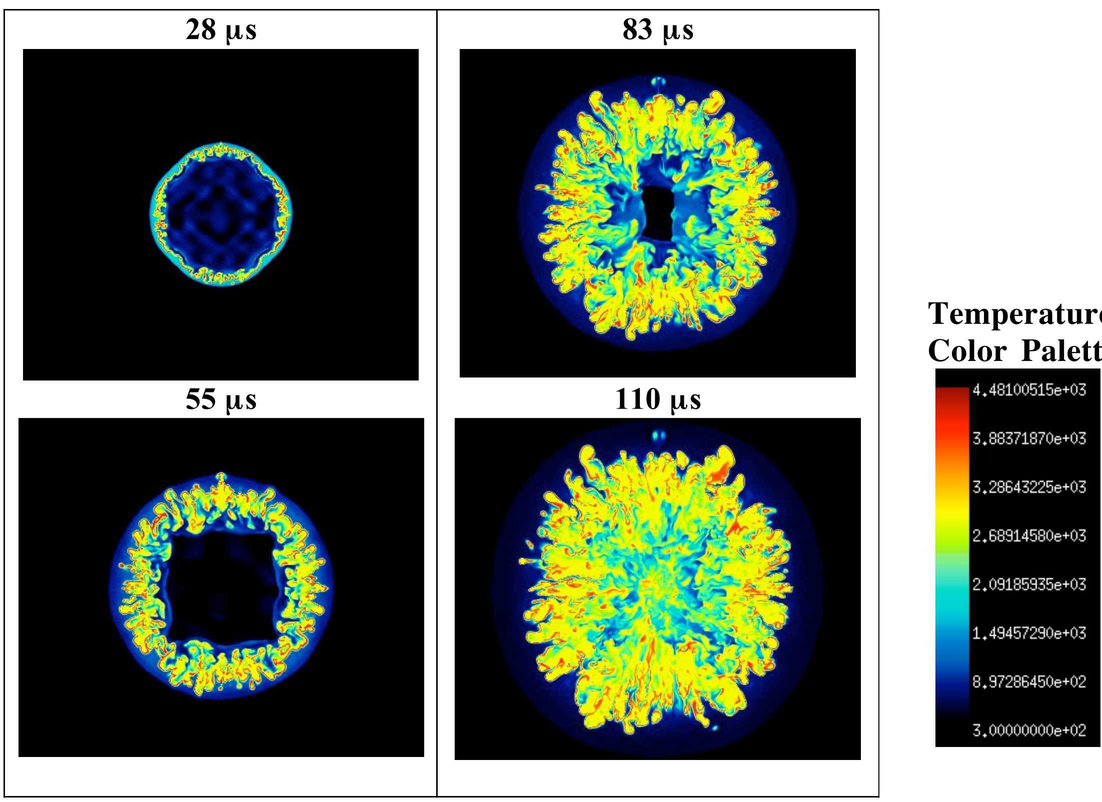


Figure 2. Cross-section views of temperature field from the explosion of a 1.5-g Al composite charge ( $D = 30\,cm$ ).

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