Oppenheim's Gasdynamic Perspective of Combustion and Explosion Phenomena

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1 Introit

Perhaps the most important contribution of Antoni Kasimierz Oppenheim (Tony) to science was his **"gasdynamic perspective"** that he brought to the analysis of combustion and explosion phenomena. This perspective started with his two Ph.D. theses of 1944: "Investigation of High-Speed Flow of Gases in Channels [1]" (University of London) and "Some Applications of the Theory of Flow to Internal Combustion Engines [2]" (Imperial College of Science and Technology). The former provided a gasdynamic formulation for one-dimensional compressible flow of ideal gases (based on Busemann's *Hand-Buch der Experimentalphyik*), while the latter applied this theoretical formulation to improve the efficiency of internal combustion engines. This two-pronged theme dominated his research for more than 60 years.

2 Perspective

In fact, Tony's research was an extended quest to sharpen the scientific perspective—both his and ours—of the **essential elements** of combustion and explosion phenomena. Tony would often say that a good combustion scientist should behave like a good sculptor (Michelangelo): he takes a large granite block (the combustion problem, containing a spectrum of physical and chemical processes accompanied by a tremendous range of physical and chemical scales) and chips away all superfluous (secondary) elements that obscure ones view (understanding), until one is left, not just with the human form (as in Michelangelo's case), but only the **skeleton** that supports/underlies the form (of combustion). For each problem, Tony's eternal question was "what are the key elements that control the exothermic process"?

Tony used to say that ***ignition*** (which depends on detailed kinetics coupled to species mass diffusion and thermal conduction) was ***the essential singularity of combustion***—the fundamental topic studied in Combustion Symposia; however, for his purposes, it was outside the scope of his "problem formulation". Ignition was presumed to occur; then what Tony wanted to investigate was the gasdynamic consequences of that exothermic energy deposition—the fundamental topic of the International Colloquia on Dynamics of Explosions and Reactive Systems (ICDERS).

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2 Examples

Examples of Tony's sharp perspective in explosions are:

- **detonation structure:** double-discontinuities, thermodynamic aspects & the Q curve [3,4]
- **wave processes** in transition to detonation in tubes [5,6]
- **vector-polar method** for the evaluation of wave interaction processes [7]
- **dynamics of exothermic reaction centers** to describe the coupling between an exothermic kernel and the explosion wave that it engenders [8,9]
- **similarity solutions** for blast waves bounded by shocks [10] or detonations [11], flame-driven blast waves [12], blast waves in exponential atmospheres [13], non-self-similar blast waves and the Method of Phase Space [14]
- **Aerodynamics of turbulent combustion fields**—based on solutions of the inviscid transport equations for vorticity and dilatation [15]
- **Thermodynamics of combustion in an enclosure**, which provides an analytic solution for the evolution of combustion processes in engines [16]
- **Pulsed Jet Combustion (PJC)** whereby one can establish a fluid-mechanic control of the combustion process in an engine cylinder [17,18]
- **Controlled Combustion Engines** [19-23]
- **Random Vortex Methods** to simulate turbulent flow in a combustion tunnel [24]
- importance of **inviscid convection** over molecular diffusion in turbulent combustion [25,26]
- dominance of **thermostatics & thermo-dynamics** over kinetics [27,28]

Here we gather these concepts under the rubric of *gasdynamics,*

3 Lecture

This ***Gasdynamic Perspective*** will be illustrated by a review of Tony's seminal publications on detonations, explosions, blast waves and combustion [1-29].

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