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Air Blast and Structural Response 2 days, 2 instructors

OVERALL OBJECTIVES:

This three-day course covers the basics of air blast generation, emphasizing detonation sources, followed by discussion of how structures respond to blast or other impulsive loading. Example problems will be worked in class. At the end of the course the student will be aware of methods and resources that he/she may draw upon to analyze blast-wave conditions and effects upon structures.

Air shocks are described in terms of source energy, thermodynamics, wave propagation and related air flows. Methods of measurement of blast parameters such as pressure and impulse will be explained. Students will become acquainted with use of equations and graphs that describe far-field blast, which follows laws of similitude. Students will understand the difference between pressure and impulse in free flow, and the reflected impulse produced in flow that may be stagnated by the presence of a structure, or even the pressure gauge. The important distinction between near-field and far-field blast behaviors will be emphasized, since use of far-field equations for a near-field problem will grossly underestimate the power of the blast. Conditions produced by confined explosions will also be described, including effects of additional energy release by combustion that follows expansion of the detonation products. Chemistry and energy release associated with enhanced-blast explosives, in which afterburn is a major factor, are described.

The response of some structures, such as explosive containment vessels, to blast loading is governed by the *impulse* imparted to the structure when the natural period of the structure is significantly longer than the pressure pulse duration. In other cases, such as blast-loaded buildings, the details of the *pressure-time history*, i.e., pulse duration, may be important. The roles of impulse and pulse duration will be demonstrated and examples will be introduced. Input (loading) parameters and output (response) quantities in dynamic structural response will be explained in the context of single-degree-of-freedom systems. Analysis of structural response to blast will emphasize computer code utilization.

LEARNING OBJECTIVES:

At course completion, each student should be able to understand and perform the following with the aid of course experience and materials.

- Distinguish between flow patterns and effects of near-field and far-field blast.
- Understand ideal-gas air-shock equations that relate to air blast.

- Use scaling-law charts for estimation of peak far-field blast pressure and positive impulse.
- Be prepared to apply measurement methods for side-on and reflected blast parameters.
- Know how to calculate or directly measure reflected impulse, which couples to structures.
- Describe behaviors of the detonation source term and structural response for confined explosions.
- Calculate additional energy that may be produced by after burn, and potential blast-wave effects of that energy.
- List relevant input loading parameters and output response parameter for dynamic loading.
- Write equations describing the response of a single-degree-of freedom system.
- Explain modal response and elastic-plastic response of dynamically loaded structures.
- Appreciate how to make use of computer codes for dynamic structural analysis
- Understand capabilities and limitations of finite-element analysis of dynamic structural response.

Progress of a student may be expected to depend on his/her degree level, degree field and professional responsibilities. Awareness of shock and detonation behaviors will promote assimilation of the concepts of air blast and blast response of structures.

<u>IMMEDIATE BENEFITS:</u>

Each student who completes this course will learn of blast-wave loading phenomena, resource materials and analysis methods he/she can use to calculate loading conditions produced by air blast and important parameters about how blast couples to structures. Regarding detonation-driven shocks, the student will understand the great differences in amplitude that may exist between detonation and deflagration, and between near-field blast, where the detonation fireball may roll over a structure, and far-field blast where the air-shock wave conveys impulse imposed upon a structure and blast-wave scaling laws apply. He/she will recognize thermodynamic conditions and kinematic effects of powerful shocks in air. The student will understand which attributes of a blast waveform relate to the response of structures loaded by the blast. He/she will understand considerations that determine whether a simplified analytical solution, scaling laws for structural response, or a finite-element computer solution is appropriate to obtain an adequate estimate of dynamic response of a structure under a given loading condition.

<u>INSTRUCTORS</u>:

The instructors for this course will be Mr. Kenneth Graham of Aerojet, Mr. Graham is coauthor of a comprehensive text on air blast, *Explosive Shocks in Air*, with Gilbert F. Kinney (1986, unfortunately out of print). He currently works mainly on insensitive munition design, and in his 40-year career has also worked on development of tests and energetic materials.