The Asia-Pacific Conference on Combustion (ASPACC) is a biennial meeting sponsored by the Combustion Institute and organized by members of the Asia-Pacific regional sections. Its goal is to promote exchange of information and to elevate combustion science and technology through regional and global scientific partnership. The 12th ASPACC will be hosted by the Japan Section of the Combustion Institute, and will be held on July 1 to 5, 2019 in Fukuoka, Japan. The conferences will provide a forum for mutual exchange of information in the Asia-Pacific combustion community involved in both fundamental and application oriented research and development works.

PLENARY SPEAKERS :

Professor Evatt Hawkes, University of New South Wales
Unravelling engine combustion using large-scale computations

Professor Naian Liu, University of Science and Technology of China
Combustion of Fire Whirl : How much do we know?

Professor Kang Y. Huh, Pohang University of Science and Technology
Combustion Modeling and Simulation in Era of the Fourth Industrial Revolution

Professor Min Suk Cha, King Abdullah University of Science and Technology
Recent understanding with flames under external electric fields

Professor Yei-Chin Chao, National Cheng Kung University
Hydrogen Peroxide Revisited : the Role as an Energy-Saving Combusiton Enhancer and a Non-Toxic Green Propellant for Satellites and Hybrid Rockets

Speakers from Japan and India Sections are to be determined.

CONFERENCE VENUE :

Fukuoka International Congress Center
2-1 Sekijo-machi, Hakata-ku, Fukuoka 812-0032, JAPAN

IMPORTANT DATES :

Submission of full paper:	25th January 2019
Notification of paper acceptance:	1st April 2019
Conference dates:	1st - 5th July 2019

PAPER SUBMISSION :

Full length papers should follow the format given on the conference web site. The Program Committee will select papers for presentation on the basis of peer reviews of each paper. All selected papers should be presented by one of the authors. Technical papers are solicited in all areas of combustion science and technology including the following areas.

- Gas-Phase Reaction Kinetics
- Soot, Nanomaterials, and Large Molecules
- Diagnostics
- Laminar Flames
- Turbulent Flames
- Spray, Droplet, and Supercritical Combustion
- Detonations, Explosions, and Supersonic Combustion
- Solid Fuel Combustion
- Fire Research
- Stationary Combustion System and Control of Greenhouse Gas Emissions
- Internal Combustion Engines
- Gas Turbine and Rocket Engine Combustion
- New Concepts

YOUNG INVESTIGATOR AWARDS :

Young Investigator Awards will be awarded to the best performing young author-presenter from research students or postdoctoral researchers (or equivalent).

BEST PAPER AWARDS :

Best paper awards will be awareded to the best papers presented at ASPACC2019.

WOMEN IN COMBUSTION MEETING :

All women conference participants are invited to join together for a time to network and share their experiences. The interactive meeting will convene during the conference.

ORGANIZING COMMITTEE :

Chair: Toshiaki Kitagawa, Kyushu University
Co-chair: Fumiteru Akamatsu, Osaka University
Co-chair: Kenji Yamamoto, Mitsubishi Heavy Industries, Ltd.
In 2019, the Organizing Committee is spread in the community of the Asia-Pacific regional sections of the Combustion Institute, mainly the Japan Section.

PROGRAM COMMITTEE :

Chair: Masato Mikami, Yamaguchi University
Co-chair: Shuhei Takahashi, Gifu University

CONTACT :

For additional information please contact
Contact address: aspacc19@combustionsociety.jp
Website: http://www.combustionsociety.jp/aspacc19/

Full length paper submission will be available in early December on the conference web.

OS7-02. Detonations, Explosions, and Supersonic Combustion

Tue., 2 Jul., 11:40 - 12:40, Room 3 (409)

Chair: **Yue Haung** (Xiamen University, China)

ASPACC2019-1161	**Numerical Investigation into Fast Deflagration and Deflagration-to-Detonation Transitions in Premixed Gaseous H_2 – O_2 - N_2 Mixtures** Weiming Liu, Joseph Owede Adoghe, Jonathan Francis (UNIVERSITY OF CENTRAL LANCASHIRE, United Kingdom)
ASPACC2019-1175	**Computation of explosion blast response in a large open space by performing adaptive mesh refinement (AMR)** Taejun Roh, Younghun Lee, Jack J. Yoh (Seoul National University, Korea)
[No Show] ASPACC2019-1396	[No Show] **Numerical Investigation of Deflagration to Detonation Transition in a Two Dimensional Duct with Obstructions** Amrutha Preethi Pathangae (Hindustan Institute of Technology and Science, India), Rahul Datta Roy, Ramanujachari V (National Centre for Combustion Research and Development, India)

12th Asia-Pacific Conference on Combustion,
Fukuoka International Congress Center, Fukuoka, Japan
1st -5th July 2019.

Computation of Explosion Blast Response in a Large Open Space by Performing Adaptive Mesh Refinement (AMR)

Tae-jun Roh[1], Young-hun Lee[1], Jack J. Yoh[1*]

[1] Department of Mechanical & Aerospace Engineering, Seoul National University

1 Gwanakro, Gwanakgu, Seoul, 151-742, Republic of Korea

Abstract

A reliable prediction of reactive flow is a difficult task when characterizing an explosive subjected to an impact as the detonation transition time is on the order of micro second. When such reactive flows are generated in air, they make pressure wave in the form of blast wave. The numerical simulation of a spherical charge detonation in a large open space is conducted and validated against experimental data. An Adaptive Mesh Refinement (AMR) method was needed to precisely track the combustion progress and the propagation of the blast wave. In addition, by merging the equations of state of two different gases, namely hot products and ideal gas, under the specific pressure and density conditions, the computational load on material interface handling in the large space domain has been significantly reduced.

1 Introduction

When detonation occurs in open space areas, the energy of reaction is released instantly in short time, and high pressure dense product gas is produced and expanded. The impulsive energy released quickly reaches equilibrium with the environment by the expansion in the air while producing multiple shock waves in the form of blast wave. The blast wave travels in open space follows a Friedlander waveform: instantaneously increasing to a maximum peak pressure well above the ambient pressure and then decaying exponentially away from the source of explosion.

Previous work in blast wave provided an empirical equation for predicting peak pressure using explosive weight and standoff distance [1]. To accurately simulate and predict the effects of blast wave propagation pertaining to specific environments, a large-scale integrated hydrodynamic simulation that can handle very large spatial dimensions is required. The reaction area length associated with a source detonator is typically a few orders of magnitude shorter than the open space domain, and thus the necessary mesh refinement suitable for blast wave propagation must be considered into one's numerical method. Also to minimize computational load in tracking interface between hot product gas and ambient air, the integration equation of state that considers both materials must be developed.

In this work, numerical simulations of a spherical charge detonation in open space area are conducted and verified against the experimental measurements.

2 Experiment

A spherical RDX of weight 5.6 kg [2] was detonated at a height of 1.8 m from the ground, allowing the explosive wave to reach and reflect from the soil ground. The characteristics of the blast wave at each segment of axial location were recorded by pressure sensors arranged at 20 m as shown in Fig. 1

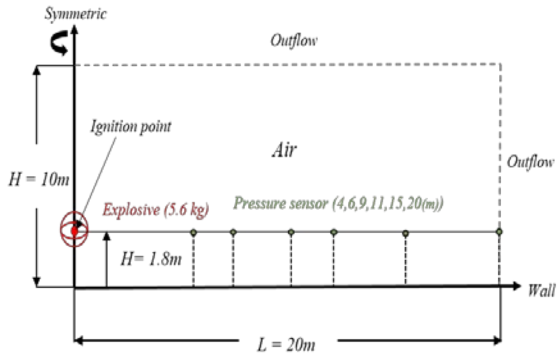

Figure 1: Experiment and simulation setup schematic.

3 Numerical approach

3.1 Governing equation

The governing equations involving mass, momentum, energy conservation, and the reaction progress are explicitly written for a 2D axisymmetric cylindrical (φ=1) and rectangular (φ=0) system as follows:

$$\frac{\partial U}{\partial t}+\frac{\partial E}{\partial x}+\frac{\partial F}{\partial y}=RHS \tag{1}$$

$$U=\left[\rho,\rho v_1,\rho v_2,\rho E,\rho\lambda\right]^{T} \tag{2}$$

$$E=\left[\rho v_1,\rho v_1^2+P,\rho v_1 v_2,v_1\left(\rho E+P\right),\rho\lambda v_1\right]^{T} \tag{3}$$

Corresponding author. Fax: +82-2-880-1507
E-mail address: jjyoh@snu.ac.kr

$$F=\left[\rho v_2,\rho v_1 v_2,\rho v_2^2+P,v_2(\rho E+P),\rho\lambda v_2\right]^{\mathrm{T}} \tag{4}$$

$$RHS=\left[0,0,0,0,\rho\dot{w}\right]^{\mathrm{T}}+R \tag{5}$$

$$R=-\frac{\varphi}{x}\left[\rho v_1,\rho v_1^2,\rho v_1 v_2,v_1(\rho E+P)\right]^{\mathrm{T}} \tag{6}$$

Here, ρ is the density, v_1 and v_2 are the velocity components in the x-, y- directions, respectively, E is the total energy per unit mass, λ is the mass fraction of the product, and P is the hydrostatic pressure. To solve the explosive detonation process and blast wave propagation, third-order Convex essentially non-oscillatory (ENO) method and the third-order Runge-Kutta (RK) method are used for spatial and time integration, respectively. A level set equation is used to track the interface and ghost fluid method is utilized for determining the conditions of materials at contact.

3.2 Reaction rate law and equation of state (EOS)

For simulating the detonation of RDX, modified Ignition & Growth model is used product mass fraction. Mie-Gruneisen EOS and non-isentropic JWL EOS are adopted for the pressure of unreacted explosive and reacted explosive respectively. For air, the ideal gas law is adopted.

$$\dot{w}=I(1-\lambda)\mu^a\Big|_{0\le\lambda\le0.01}+G(1-\lambda)P^b\Big|_{0.01\le\lambda\le1}\ ;\ \mu=\frac{\rho}{\rho_0}-1 \tag{7}$$

$$P_{Mie-Gruneisen}=P_{\mathrm{H}}+\Gamma\rho(\mathrm{e}-\mathrm{e}_H);\ V=\frac{\rho_0}{\rho} \tag{8}$$

$$P_{JWL}=A_1\left(1-\frac{w_1}{R_{11}V}\right)e^{-R_{11}V}+B_1\left(1-\frac{w_1}{R_{12}V}\right)e^{-R_{12}V}+w_1\frac{E}{V} \tag{9}$$

$$;V=\frac{\rho_0}{\rho}$$

3.3 Adaptive mesh refinement (AMR)

To simultaneously simulate the point source detonation and its blast wave propagation in a large computational domain, cell-based AMR is implemented to allocate required computational resources at regions where high mesh resolution is critical. The mesh division proceeds prior to calculating the fluxes. The differences of physical quantities such as ρ (density), P (pressure), E (internal energy) are calculated for all existing cells in order to determine which region requires a finer mesh for accurately capturing the physical length scale associated with the discontinuous zone. The refined cell is removed if it is no longer required.

The reaction zone length is the distance from the start of the reaction to the point where the reaction completes up to 99%. The reaction zone length of the considered explosive is about 5 mm, and the mesh size must be less than it. At the same time, the computational domain of open space is as large as 20 meters in length and 10 meters in height. The AMR technique developed for this purpose uses 2 mm mesh size in the reaction zone that moves with blast wave propagation while the coarse mesh of 64 mm is used otherwise as shown in Fig. 2. There was little difference in blast peak pressure values between 1 mm and 2 mm mesh size at the final stage of AMR.

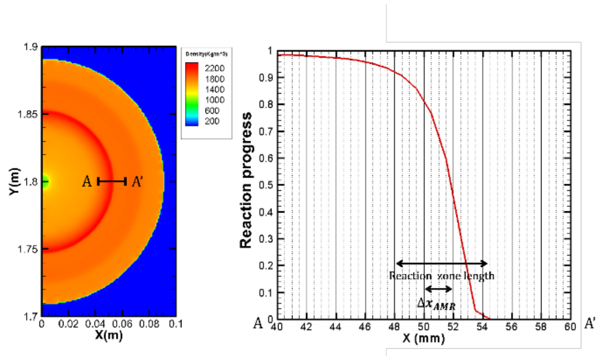

Figure 2: Left: point source detonation process shown density contour. Right: reaction progress shown with AMR minimum mesh size and reaction zone length.

3.4 Integration of two different equations of state

Level-set method and ghost fluid method are used to track interface and determine boundary conditions between two distinct materials since EOSs are different in each material. When detonation process is completed, and the EOS of the reacted explosive expressed as Eq. 9 is equal to the ideal gas equation in air, and therefore, two independent EOSs are no longer necessary. In order to reduce the computing load for large domain of computation, the following integration technique is used. In Eq. 9, the contributions from each of the three right-hand-side terms are plotted in Fig. 3, and labeled A term, B term, and C term. When the density and pressure drops below certain values, A term and B term do not contribute as C term is the only effective term. Such JWL EOS finally converges to C term which is identical with an ideal gas law with added heat of detonation. Therefore, when the highest density and pressure in simulation are below the values, ρ^* and P^*, the mentioned integration of two EOSs is performed.

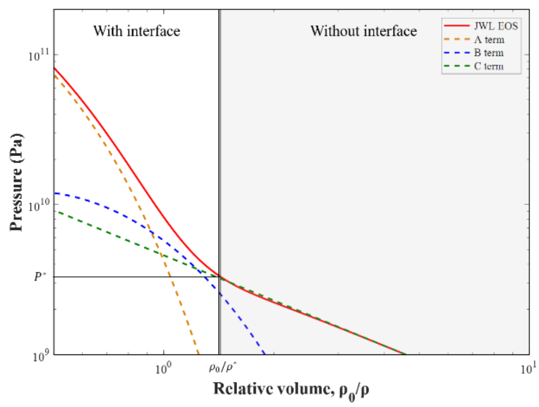

Figure 3: JWL EOS showing critical P^* and ρ^* for integration .

4 Results and discussion

The simulation of the point source detonation followed by blast wave propagation in open space (20 meter by 10 meter) area is performed, and the results are compared against the experiment. The initial conditions shown in Fig. 1 are used. As blast wave travels, the computational mesh is finely divided to capture the discontinuities associated with the transient zone. Fig. 5 shows the pressure contour that includes the incident wave propagation with subsequent wave interactions with the reflected waves. Fig. 4 shows the time history of pressure at the sensor 1 located 4m from the source charge. High pressure two peaks are identified in Fig. 4. The first peak is created from the incident wave and the second peak is from the reflected wave effect. Table 1 and 2 summarize the peak pressure and impulse at six distinct sensor locations. The comparison of the calculation with measurement is within 3.5 % error in the peak pressure while impulse had less than 6.8% discrepancy in quantitative comparison.

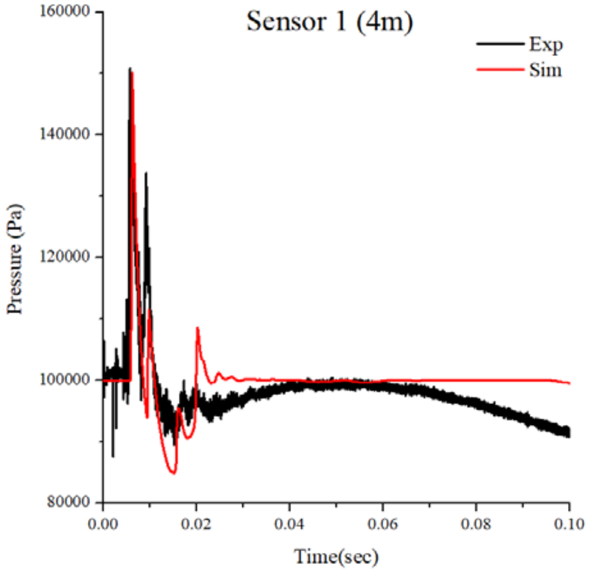

Figure 4: Pressure history at sensor 1 (4m).

	Peak pressure(Pa)		Error(%)
	experiment	simulation	
4m	147200	151100	2.64
6m	128400	125870	1.97
9m	117024	115440	1.35
11m	117640	113640	3.40
15m	113330	109440	3.43
20m	108970	106250	2.49

Table 1: Peak pressure comparison between experiment and simulation.

	Impulse(Pa*sec)		Error(%)
	experiment	simulation	
4m	90.1647	90.6250	0.51
6m	82.2594	83.7860	1.85
9m	64.0226	67.5760	5.55
11m	62.2581	61.7210	0.86
15m	50.1281	52.6930	5.11
20m	42.5657	45.4830	6.85

Table 2: Impulse comparison between experiment and simulation.

5 Acknowledgment

This study was carried out with the support of Agency of Defense Development. The authors are grateful to Dr. J. Park of ADD for providing the experimental data.

References

[1] C.N. Kingery, G. Bulmash, Airblast parameters from TNT spherical air burst and hemispherical surface burst, Report ARBL-TR-02555, U.S. Army BRL, Aberdeen Proving Ground, MD, 1984.

[2] D. Baek, B. Kim, J.J. Yoh, J. Appl. Phys. 124 (21) (2018) 215905.

[3] Y. Lee, W. Lee, M, Gwak, K. Kim, J.J. Yoh, J. Appl. Phys. 124 (2018) 145903.

[4] L. Donahue, F. Zhang, R.C. Ripley, Shock Wave. 23 (6) (2013) 559-573.

[5] M. Gwak, Y. Lee, K. Kim, J.J. Yoh. Int. J. Hydrogen Energ. 40 (7) (2015) 3006-3014.

[6] E. Schnetter, H. Scott, I. Hawke Class. Quantum Grav. 21 (6) (2004) 1465–1488.

[7] B. Kim, J. Park, K. Lee, J.J. Yoh J. Appl. Phys. 116 (2014) 023512.

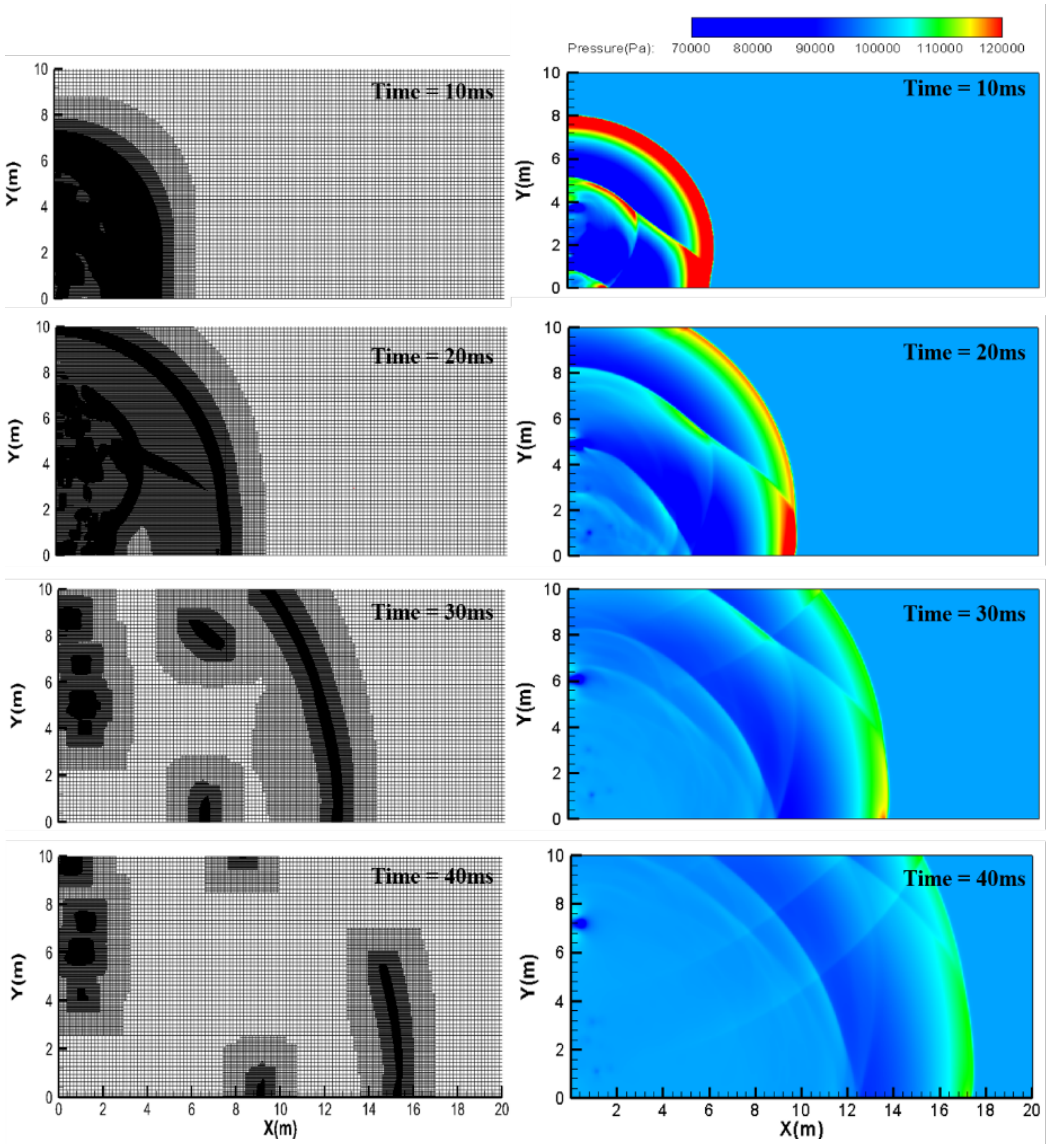

Figure 5: Adaptive mesh refinement process (Left) and pressure contour (Right) at 10, 20, 30, 40 ms.