

船艦水屏防禦之研究

曾韋銘、梁卓中

E-mail: 9511331@mail.dyu.edu.tw

摘要

本論文乃是以線串炸藥 (line charge) 於水下爆炸形成水屏防禦 (Barrier defense) 之分析為研究對象。在1995年7月間，美國海軍水面戰鬥中心 (Naval Surface Warfare Center Dahlgren Division, NSWCCD) 發展出一種新的技術概念，此概念即認為應用水下爆炸產生之水屏形成之防禦系統可有絕對之效益，尤其應用在海軍防禦對抗高速反艦飛彈 (ASCMs) 之攻擊。水屏技術乃運用較低經費之水下爆炸產生之水屏來提供海軍最低限度之防禦系統。此類水屏或水障壁 (Barrier) 的產生來自於多顆水下炸藥在淺水下爆炸而成。為了持續發展以及水障壁概念的評估，NSWCCD進行了線串炸藥之水下爆炸測試，探討離散型 (Discrete) 及連續型 (Continuous) 線串炸藥爆炸後噴入空氣中的水量所產生之水屏的防禦能力。本論文以美國NSWCCD之水屏試驗場景及量測結果為研究與驗證對象，利用MSC.Dytran軟體進行自由液面水柱之模擬探討，分析離散型線串炸藥與連續型線串炸藥二種型態之線串炸藥於水面下引爆後，探討厚度、高度及密度對產生水屏之影響，由二維之連續型與離散型線串炸藥模型以及三維之離散型線串炸藥模型所計算出之結果，比較水屏高度、密度及剖面圖之輪廓。最後，由二維及三維線串炸藥爆炸研究探討優質水屏之理想爆炸深度及其產生之水柱輪廓。

關鍵詞：反艦飛彈；水障壁；水屏；線串炸藥

目錄

COVER CREDENTIAL AUTHORIZATION LETTERS iii	ABSTRACT (CHINESE) iv	ABSTRACT (ENGLISH) v																										
ACKNOWLEDGEMENTS vii	TABLE OF CONTENTS vi	LIST OF FIGURES viii	LIST OF TABLES x	SYMBOLS xiii																								
Chapter I. INTRODUCTION 1	1.1 Motivation 1	1.2 Literature survey 2	1.2.1 The physical phenomena of underwater explosion 3	1.2.2 The water barrier of underwater explosion 5	1.3 Purpose 6																							
Chapter II. THEORETICAL BACKGROUND 10	2.1 Eulerian equation of motion 10	2.2 Equation of state 12	2.3 Ignition and growth explosive material model 13	2.4 Numerical approach 17																								
Chapter III. MICHAEL ' S SEMI-EMPIRICAL FORMULATION FOR WATER PLUME OF UNDERWATER EXPLOSION 29	Chapter IV. NUMERICAL VALIDATION 33	4.1 Numerical validation for single charge 33	4.2 2-D model for single charge underwater explosion 33	4.2.1 Problem description 33	4.2.2 Model description 33	4.2.3 Results and discussion 35	4.3 3-D model for single charge underwater explosion 35	4.3.1 Model description 36	4.3.2 Results and discussion 36	4.4 Comparison and discussion 37																		
Chapter V. NUMERICAL STUDY OF WATER BARRIER 46	5.1 Continuous line charge for constant depth using 2-D numerical model 46	5.1.1 Problem description 46	5.1.2 Model description 47	5.1.3 Results and discussion 48	5.2 Discrete line charge for constant depth using 2-D model and 3-D numerical model 49	5.2.1 Problem description 49	5.2.2 Model description 49	5.2.3 Results and discussion 51	5.3 Comparison of 2-D and 3-D numerical model for line charge underwater explosion 51																			
Chapter VI. CONCLUSIONS 67	6.1 Conclusions 67	6.2 Futures works 69																										
REFERENCES 71	TABLE OF FIGURES	Fig. 1.1. Water plume of an underwater explosion for ship self-defense 8	Fig. 1.2. Water plume of an underwater explosion 8	Fig. 1.3. Development of base surge from an underwater explosion 9	Fig. 2.1. A mixture zone in the IG explosive element 25	Fig. 2.2. Flow chart for IG model solution 26	Fig. 2.3. Euler element CHEXA 27	Fig. 3.1. Plume dimension 30	Fig. 3.2. Maximum height and radius of the plume from an underwater TNT explosion 31	Fig. 4.1. Configuration of 0.445kg TNT charge fired at depth of 1.5 meter 38	Fig. 4.2. 2-D geometrical model of water plume 39	Fig. 4.3. 2-D finite element model of water plume 39	Fig. 4.4. Maximum height of plume for 0.445kg TNT charge underwater explosion 40	Fig. 4.5. 3-D geometrical model of water plume 41	Fig. 4.6. 3-D finite element model of water plume 41	Fig. 4.7. Maximum height of water plume using 3-D model 42	Fig. 5.1. Continuous line charge arrangement at constant depth 53	Fig. 5.2. 2-D geometrical model of continuous line charge 54	Fig. 5.3. 2-D finite element model of continuous line charge 54	Fig. 5.4. Maximum height of plume for continuous line charge 55	Fig. 5.5. Discrete line charge arrangement at constant depth 56	Fig. 5.6. 2-D geometrical model of discrete line charge 57	Fig. 5.7. 2-D finite element model of discrete line charge 57	Fig. 5.8. 3-D geometry of discrete line charge 58	Fig. 5.9. 3-D finite element model of discrete line charge 59	Fig. 5.10. Maximum height of water barrier of discrete line charge for 2 – D model, 3-D model and Joseph experiment 60	Fig. 5.11. Maximum length of water barrier of discrete line charge for 2 – D model, 3-D model and Joseph experiment 60	Fig. 5.12. Maximum diameter of water barrier of discrete line charge for 3-D model and Joseph experiment 61
LISTS OF TABLES	Table 2.1. Material parameters and coefficients in the EOS for water 28	Table 2.2. Coefficients for the IG model of several explosions in the database 28	Table 3.1. Maximum height and radius of the plume from an underwater TNT																									

explosion 32 Table 4.1. Surface effect of underwater explosion (TNT charge weight:0.445kg, fired depth: 1.5m) using 2-D model 43 Table 4.2. Surface effect of underwater explosion (TNT charge weight:0.445kg, fired depth: 1.5m) using 3-D model 44 Table 4.3. Surface effect of underwater explosion (TNT charge weight:0.445kg, fired depth: 1.5m) using 3-D model (continuous) 45 Table 5.1. Surface effect of underwater explosion of continuous line charge 62 Table 5.2 Surface effect of underwater explosion of continuous line charge (continuous) 63 Table 5.3 Surface effect of underwater explosion of discrete line charge 64 Table 5.4 Surface effect of underwater explosion of discrete line charge (continuous) 65 Table 5.5 Diameter of water barrier of discrete line charge using 3-D model 66

參考文獻

- [1]Naval Sea Systems Command, Water Barrier Ship Self-Defense, Nswc.Navy.Mil/P/Recruit/Recruit.Html.
- [2]Keil, A.H., The Response of Ships to Underwater Explosions. Annual Meeting of SNAME, New York, 1961.
- [3]James E. C., Young S. S., Explosion Gas Bubble Near Simple Boundaries. Shock and Vibration, Vol.4, No.1, 11-25, 1997.
- [4]Suresh Menon and Mihir Lab, On the Dynamics and Instability of Bubbles formed During Underwater Explosions. Experimental Thermal and Fluid Science 16, 305-321, 1998.
- [5]Kenji Murata, Katsuhiko Takahashi and Yukio Kato, Precise Measurements of Underwater Explosion Phenomena by Pressure Sensor using Fluoropolymer. Journal of Materials Processing Technology 85, 39-42, 1999.
- [6]Akio kira, Masahiro Fujita and Shigera Itoh, Underwater Explosion of Spherical Explosives. Journal of Material Processing Technology 85, 64-68, 1999.
- [7]M. B. Lin, G. R. Liu, Z. Zong and K. Y. Lam, Computer Simulation of High Explosive Explosion using Smoothed Particle Hydrodynamics Methodology. Computers and Fluids 32, 305-322, 2003.
- [8]M. B. Lin, G. R. Liu, K. Y. Lam and Z. Zong, Smooth Particle Hydrodynamics for Numerical Simulation of Underwater Explosion. Computational Mechanics 30, 106-118, 2003.
- [9]C. Wang, B. C. Khoo and K. S. Yeo, Elastic Mesh Techniques for 3D BIM Simulation with an Application to Underwater Explosion Bubble Dynamics Computer and Fluids 32, 1195-1212, 2003.
- [10]S. Rungsiyaphornrat, E. Klaseboer, B. C. Khoo and K. S. Yeo, The Merging of Two Gaseous Bubbles with an Application to Underwater Explosions. Computer and Fluids 32, 1049-1047, 2003.
- [11]Carruthers D.J., Dyster S.J. and Ellis K.L, PLUME VISIBILITY. ADMS,3 P26/01D/03, 2003.
- [12]C Wang and B.C. Khoo, An Indirect Boundary Element Method for Three-Dimensional Explosion bubbles. Journal of Computational Physics 194, 451-480, 2004.
- [13]C. C. Liang, Y. S. Tai, T. H. Liu, A Study of the Effects of Underwater explosions. Journal of Taiwan Society of Naval Architects and Marine Engineers, R.O.C., Vol.24, No.1, 39-57, 2005.
- [14]Ship System Project, Ship Protection Study, II-TD-32, PFG-I, 1982.
- [15]Cole, R.H., Underwater Explosions. Princeton University Press, Princeton, 1948.
- [16]Michael M., Swisdak, JR., Explosion and Properties Part -Explosion Effects in Water. Naval Surface Warfare Center, NSWC/WOL/TR-76-116, 1978.
- [17]Joseph G.. Connor and Charles E. Higdon, Water Barrier Line Charge Plume Video Analysis. DAHLGREN DIVISION NAVAL SURFACE WARFARE CENTER, NSWCDD/TR-96/178, Naval Surface Warfare Center, Dahlgren Division (Code G23), 17320 Dahlgren road, Dahlgren, VA 22448-5100, October, 1996.
- [18]Charles E. Higdon, William G. Szymczak, and Joseph G. Connor, Analysis of Water Barrier Line Charge Plume Measurements. NSWCDD/TR-97/210, Naval Surface Warfare Center, Dahlgren Division (Code G23), 17320 Dahlgren road, Dahlgren, VA 22448-5100, January, 1998.
- [19]William G. Szymczak, and Charles E. Higdon, Model Validations and Predictions for Water Barrier Defense. Naval Research Laboratory, Washington, DC 20375-5320, Office of Naval Research, 800 North Quincy Street, Arlington, VA 22217-5660, May 12, 1998.
- [20]C. C. Liang, T. H. Liu, W. M. Tseng., Model Validations and Predictions of Water Plume Behavior of Underwater Explosion Near Air-Water Surface. Journal of Taiwan Society of Naval Architects and Marine Engineers, R.O.C., Vol.25, No.1, 17-33, 2006.
- [21]MSC.Dytran " User ' s Manual " . Mac Neal-Schwendler Corporation, Version 4.7, Los Angeles, CA, 2002.
- [22]Peiran Ding, and Arjaan Buijk, Simulation of Underwater Explosion using MSC.Dytran. MSC.Software Corporation, 2300 Traverwood Drive, Ann Arbor, MI 48105, (734) 994-3800, 2005.