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A Numerical Study on the Velocity of a Cylindrical Counter Projectile Using LX-14 Explosive

Kyung Jin Kim[1, a], Jahng-Hyon Park[2,b], Jong-Bong Kim[3,c]

[1]School of Mechanical and Automotive Engineering, Kyungil University, 50, Gamasil-Gil, Hayang-Eup, Gyeongsan-Si, Gyeongbuk, 712-701, Korea

[2]Dept. of Automotive Engineering, Hanyang University, 17, Haengdang-Dong, Seongdong-Gu, Seoul, 133-719, Korea

[3]Dept. of Mechanical and Automotive Engineering, Seoul Nat. Univ. Sci. Technol., 172, Gongneung-2 Dong, Nowon-Gu, Seoul, 139-743, Korea, Corresponding author

[a]kkj@kiu.ac.kr, [b]jpark@hanyang.ac.kr, [c]jbkim@seoultech.ac.kr

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Abstract. In order to develop an active protection system for armored vehicles, the launching process of a cylindrical rod-shaped interception projectile was analyzed. The variations of the movement and the velocity of the interception projectile according to the mass ratio of the interception projectile to the LX-14 explosive were simulated using AUTODYN. Simulated results showed that the mass ratio of the interception projectile to the explosive plays a dominant role in determining the final velocity of the interception projectile.

Introduction

Traditionally, armored vehicles have been protected by heavy structures with steel which may cause mobility problems due to the heavy weight of the armor on the battle field. And along with the continuous development of intelligent anti-tank projectiles, armored vehicles encounter an increasingly serious threat. The armor protection system has to develop new technologies so as to enhance the armored vehicles' survivability and mobility on the battle field. Active protection systems are designed to defeat a wide range of threats for armored vehicle. Anti-tank projectile will deviate from its trajectory or be destroyed completely when hit by the interception projectile. Fig. 1 shows a schematic description of an active protection system for armored vehicles using interception projectiles.

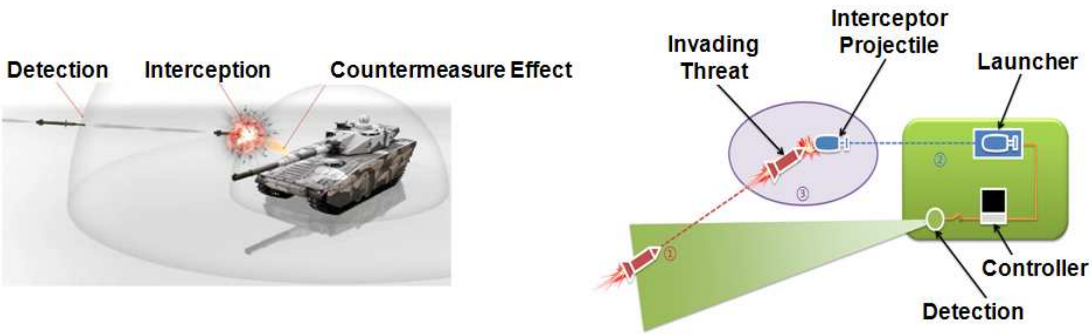

Fig. 1. Schematic description of active protection system for armored vehicles

Rosenberg et al. [1] reviewed the important mechanisms for defeating various projectiles and shaped charge jets; they proposed some and some patents for active protection systems to defeat invading threats [2-4]. In this paper, a numerical model of an interceptor projectile based on a launcher using LX-14 explosive was introduced. The launching process of the cylindrical rod-shaped interception projectile was analyzed. Numerical simulations for the variations of the movement and the velocity versus time during the launching of the interception projectile were carried out using a commercial hydrocode, AUTODYN [5]. The relationships between the muzzle velocity of the interceptor and the mass ratio of the interceptor to the LX-14 explosive were investigated.

Numerical Modeling for the Launcher of Interceptor Projectile

A schematic illustration and numerical model for the launcher of the interception projectile are shown in Fig. 2. The propellant for launching the projectile is LX-14 explosive; the basic properties of LX-14 are shown in Table 1. The interception projectile is a cylindrical rod and the LX-14 explosive is charged at the breech in the launcher. After detonation of the explosive, the projectile begins to move forward due to the pressure rise at the projectile base. In the numerical model, the configuration of the launcher, projectile, and explosive is assumed to be axisymmetric. The interception projectile is modeled with the Lagrange method in steel 4340 (density : 7.83 g/cm^3) and the launcher, which is modeled with Eulerian method, is fixed in the air. There is a gap of 1 mm between the projectile and the wall of the launcher in order to reduce the resistance force due to friction. The projectile velocity for a different mass ratio of projectile to explosive was obtained and investigated. Three different mass ratios and three different projectile masses were subjected to analysis. The mass ratios of the projectile to the explosive that were considered were 10 : 0.5, 10 : 1, and 10 : 2; the velocity of the projectile was evaluated for masses of the projectile of 10 kg, 30 kg, and 50 kg for each case of the mass ratio. The detailed geometrical dimensions of the numerical model for the launching system are shown in Table. 2.

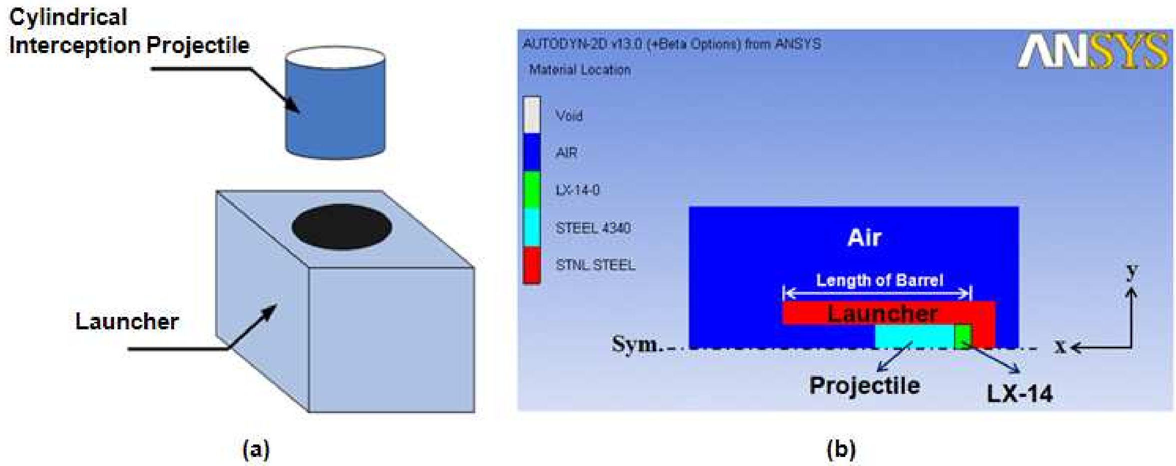

Fig. 2. (a) Schematic illustration and (b) numerical model for the launching system of interception projectile

Table 1. Properties of LX-14 explosives

Density [g/cm^3]	1.83
Velocity of Detonation [m/s]	8,740
Energy/Unit Volume [KJ/m^3]	1.02e7
Temperature after Explosion [℃]	1300

Table 2. Geometrical dimensions of numerical model for launching system according to the mass of interception projectile

Mass of Interception Projectile [kg]	10	30	50
Diameter of Interception Projectile [mm]	98	198	198
Length of Interception Projectile [mm]	170	120	210
Length of Barrel [mm]	400	300	500

Results and Discussion

During the motion of the projectile in the barrel, the internal energy of the LX-14 explosive is progressively converted into kinetic energy, which causes the projectile to accelerate along the barrel until emerging from the muzzle. Fig. 3 shows the simulation results of the launching process with an interception projectile of 50 kg and LX-14 explosive of 5 kg. Other simulations with different masses of the projectile and LX-14 show launching processes similar to those shown in Fig. 3. And comparisons of the time history of projectile velocity according to the mass ratio of the interception projectile to the LX-14 explosive are shown in Fig. 4. It is clear that the velocity histories have similar tendencies for every simulation, even though the final velocities are different.

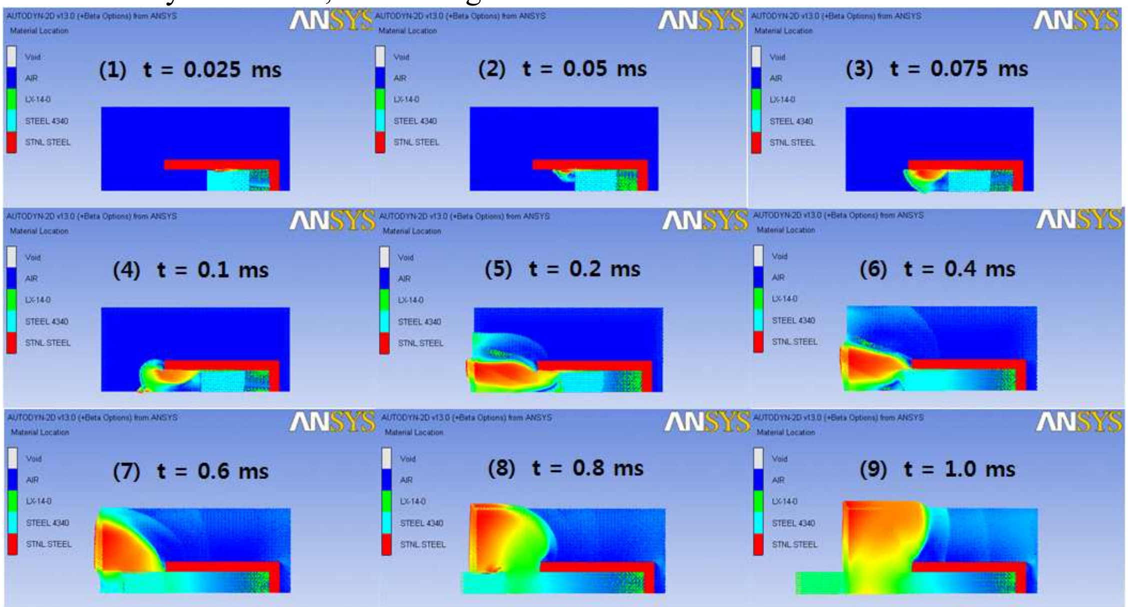

Fig. 3. Simulation results of the launching process of an interception projectile of 50 kg and LX-14 explosive of 5 kg

As can be seen in Fig. 3, at the beginning of the launching process, high pressure from the detonation of the LX-14 explosive is suddenly released and acts on the rear face of a projectile enclosed inside a barrel, which begins to accelerate the projectile. Then, the high pressure causes the escape of gas through the gap between the interception projectile and the wall of the barrel. This escape of gas raises the pressure on the frontal face of the projectile, which retards the acceleration of the projectile because the pressure difference across the projectile accelerates the projectile along the barrel. This deceleration of the projectile can be found during 0.1 ~ 0.2 ms in all the velocity histories shown in Fig. 4. Then the projectile is accelerated continuously until the projectile moves out of the muzzle.

Evaluation of the final velocity of the projectile leads to the conclusion that the mass ratio of the projectile to LX-14 has a strong relationship with the projectile velocity. The final velocities of the interception projectiles after moving out of the muzzle, according to the mass ratio, are compared in Table 3. The simulated results show that the muzzle velocities can be about 550 m/s, 820 m/s, and 1100 m/s in the cases of 10 : 0.5, 10 : 1, and 10:2 mass ratios of projectile to LX-14 explosive, respectively.

Summary

In this paper, two-dimensional axisymmetric numerical simulations using AUTODYN were applied to the launching process of an interception projectile. The simulated results show that there is a strong relationship between the muzzle velocity and the mass ratio of the interception projectile to the LX-14 explosive.

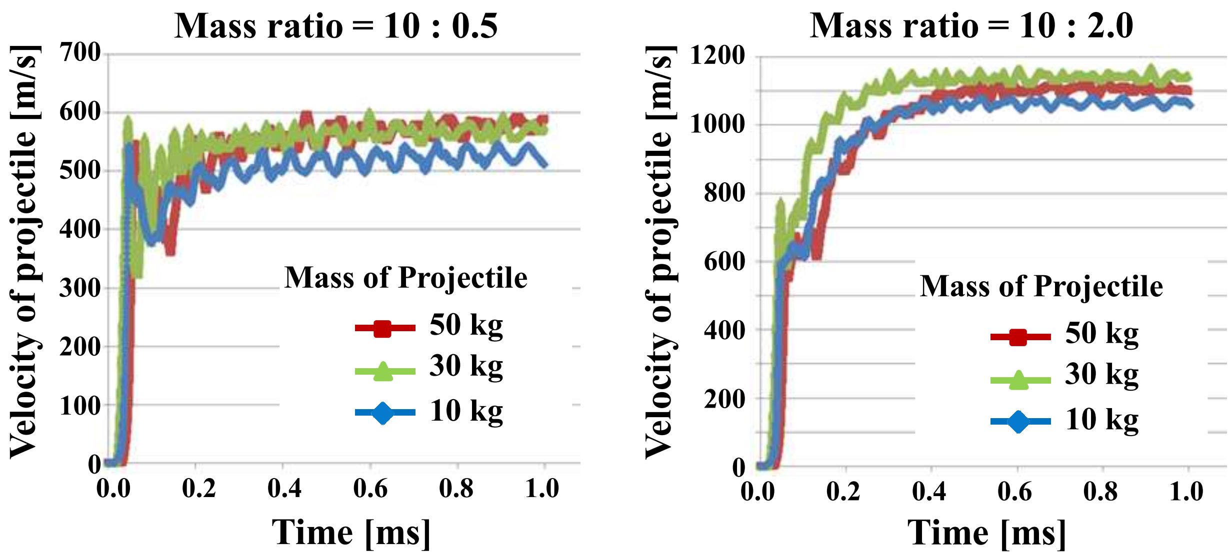

Fig.4. Comparisons of projectile velocities according to the mass ratio of interception projectile to LX-14 explosive

Table 3. Muzzle velocity of interceptor projectile according to the mass ratio of interceptor to LX-14 explosive

Mass Ratio of Interceptor to LX-14	Mass of Interceptor [kg]	Muzzle Velocity [m/s]
10 : 0.5	10	525
	30	571
	50	574
10 : 1	10	787
	30	844
	50	825
10 : 2	10	1063
	30	1142
	50	1105

Acknowledgements

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References

[1] Z. Rosenberg, Y. Ashuach, Y. Yeshurun and E. Dekel, Int. J. of Impact Eng., Vol. 36, (2009), p. 588

[2] P. G. Lloyd, U.S. Patent 6,782,793. (2004)

[3] Y. W. Chang, U.S. Patent 7,104,496. (2006)

[4] A. Kerdraon, M. Vives, J-P. Toussirot and G. Lefebvre, U.S. Patent 6,327,955. (2001)

[5] Century Dynamics Inc., AUTODYN User's manual (2005)