engineering proceedings

Proceeding Paper

Numerical Simulation Analysis of Penetration Performance of Armor-Piercing Fin-Stabilized Discarding Sabot to Steel Plate †

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† Presented at the 3rd IEEE International Conference on Electronic Communications, Internet of Things and Big Data Conference 2023, Taichung, Taiwan, 14–16 April 2023.

Abstract: An armor-piercing fin-stabilized discarding sabot is used with a spare shell for 30 mm chain artillery. Due to the limited firepower of the bomb, the limited domestic shooting range, and the high public awareness of environmental protection, it is not easy to test the intrusion force. Therefore, an armor-piercing fin-stabilized discarding sabot is simulated and analyzed to optimize the design of tungsten composition to save research and development costs and improve ammunition performance. The key work of this research includes three parts: pre-work, armor-piercing fin-stabilized discarding sabot drawing, and numerical simulation analysis. Establishing a basic reference data system for ammunition specifications is currently being developed through finite element simulation analysis including the establishment of an armor-piercing fin-stabilized discarding sabot model and performing optimization design evaluation analysis.

Keywords: armor-piercing fin-stabilized discarding sabot; intrusion force; finite element simulation analysis

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Citation: Wang, Y.-S.; Hsu, C.-H. Numerical Simulation Analysis of Penetration Performance of Armor-Piercing Fin-Stabilized Discarding Sabot to Steel Plate. *Eng. Proc.* **2023**, *38*, 76. https://doi.org/10.3390/engproc2023038076

Academic Editors: Teen-Hang Meen, Hsin-Hung Lin and Cheng-Fu Yang

Published: 10 July 2023

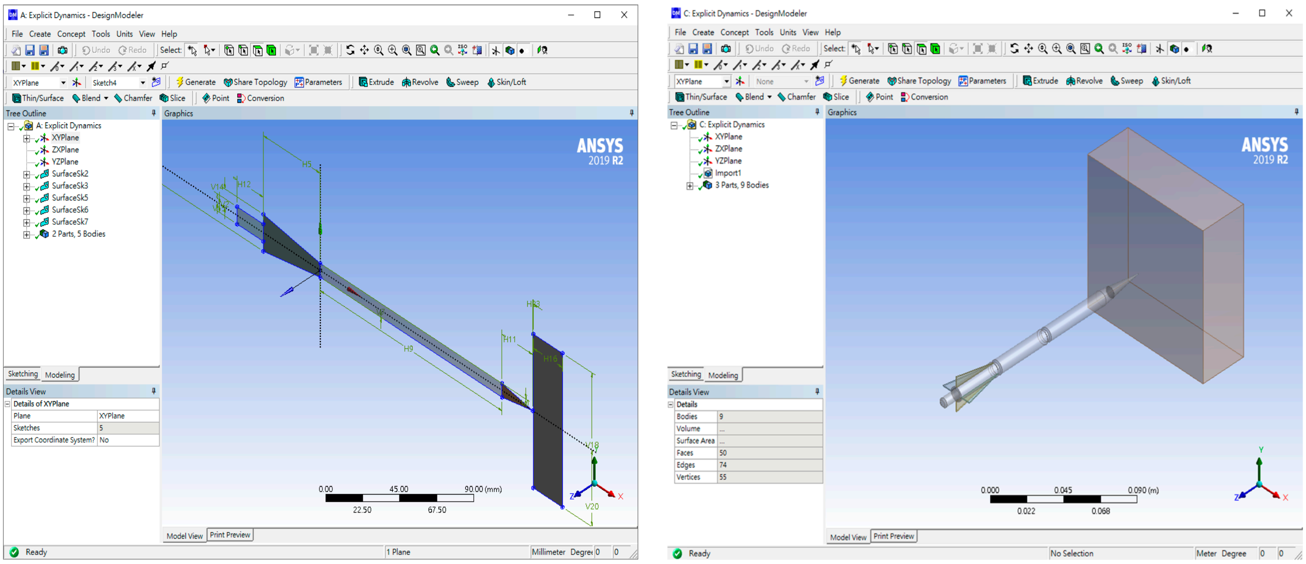
1. Introduction

At present, the production accuracy of 30 mm wing stable shelling armor-piercing tracers is stable [1–3]. In order to make the tracer suitable for use in various countries, it is necessary to improve the bullet's appearance to improve the speed and accuracy of the bullet [4,5]. The cost of mold production is relatively high, considering factors such as saving the defense budget and saving costs. The focus of this research is to establish a 30 mm wing-stabilized shelling armor-piercing tracer and different steel plate thickness models through finite element simulation analysis. Finite element analysis is used to set the density and impact speed of each tungsten rod, and the optimized mathematical calculation module is used. This research conducts analysis and uses materials and processes to construct physical bullets for comparative analysis, and through the big data database, to verify the reliability of the mathematical parameter calculation module of this research, and to implement the database construction and function integration.

2. Numerical Analysis

2.1. 30 mm Armor-Piercing Fin-Stabilized Discarding Sabot Geometry

Using the ANSYS Workbench finite element analysis software graphics design tool, and according to the size of the 30 mm wing-stabilized shell-piercing tracer projectile, the 2D and 3D drawing files of this type of projectile were constructed, as shown in Figure 1.



(**a**) (**b**)

Figure 1. Build model: (**a**) 2D model and (**b**) 1D model.

2.2. Reference Armor Firing Rate

According to the US military technical manual MIL-STD-367 and MIL-STD-662F specifications as shown in Table 1, the shooting muzzle velocity is 1430 m/s, the simulated vertical target position is 1000 m away from the muzzle, and the impact velocity is 1306 m/s.

Table 1. Distance and impact speed comparison table.

Range (Meter)	Remain Velocity (m/s)
0	1430
100	1417.6
200	1405.2
300	1392.9
400	1380.5
500	1368.1
600	1355.7
700	1343.3
800	1330.9
900	1318.5
1000	1306.1

2.3. Two-Dimensional and Three-Dimensional Models for Simulation Analysis

According to the 30 mm wing stable shelling armor-piercing tracer material to select tungsten alloy material from the built-in database of ANSYS in Table 2, it is confirmed that the material properties are consistent with this analysis, and the 2D and 3D image files are imported to use the ANSYS Explicit Dynamics module for mesh analysis. The number of nodes is 21,198 and the number of grids is 20,422. The analysis and calculation module function confirm that the grid has converged and set the boundary condition parameters for the armor-piercing tracer and steel plate.

Table 2. Tungsten rod material parameters.

	A	B	C
1	Property	Value	Unit
2	Density	17,790	kg mˆ − 3
3	Young's Modulus	3.9×10^{11}	Pa
4	Poisson's Ratio	0.28	
5	Bulk Modulus	2.9545×10^{11}	Pa
6	Shear Modulus	1.5234×10^{11}	Pa
7	Yield Strength	84,000	psi
8	Tangent Modulus	130	psi
9	Specific Heat, C_p	184	J kgˆ − 1ˆ − 1

3. Results and Discussion

Through ANSYS finite element analysis, the armor-piercing tracer and the steel plate are set to be 1000 m away from the muzzle, and the thickness of the steel plate is set to 25, 35, 40, and 50 mm, and various mechanical analyses are performed through the post-processing module function. The strain data obtained from tracer bullets and steel plates of various thicknesses are shown in Figure 2.

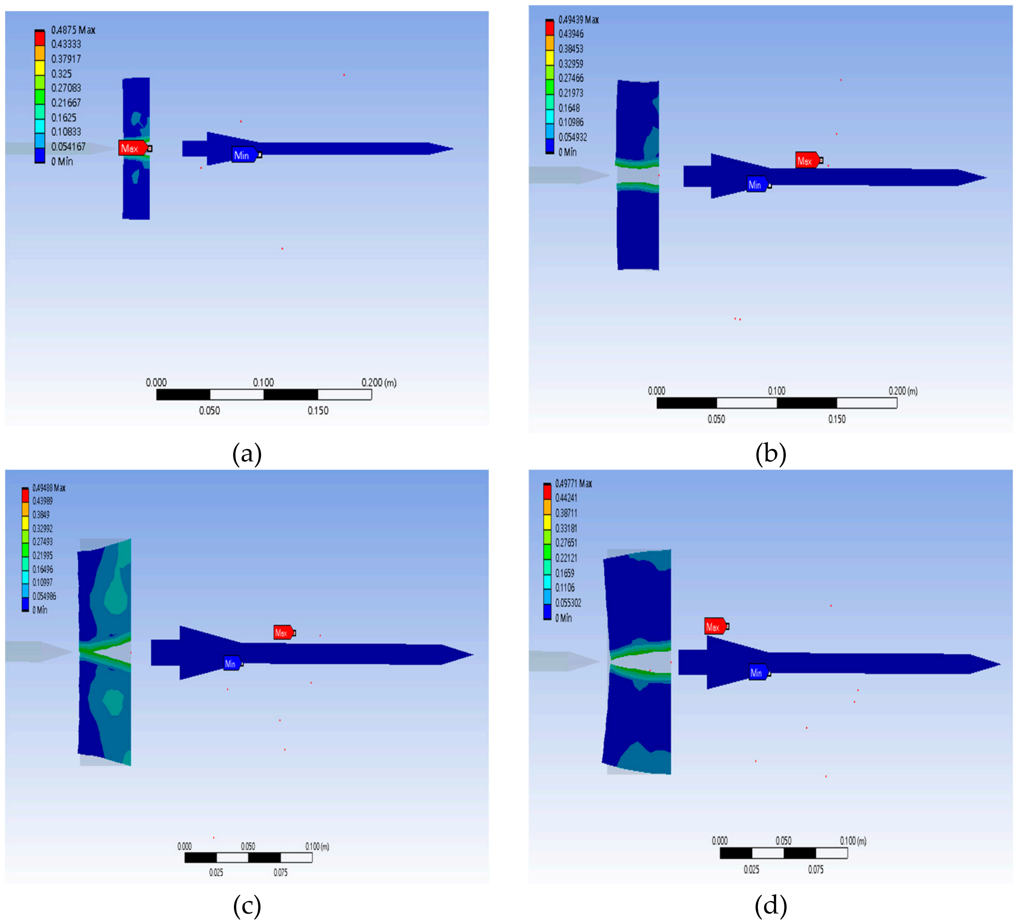


Figure 2. Steel plate thickness and strain analysis. (**a**) Thickness: 25 mm; (**b**) thickness: 35 mm; (**c**) thickness: 40 mm; (**d**) thickness: 50 mm.

If the density of the armor-piercing projectile does not change, by changing the boundary condition setting of the impact speed from 1000 to 1300 m/s, the armor-piercing projectile is affected by the speed, and the penetration depth continues to increase. This causes certain damage to various types of tank armor. The effect is shown in Table 3.

Table 3. Comparison table of relationship between impact speed and penetrable depth.

Rate of Fire (m/s)	Distance (m)	Density (g/cm^3)	Penetration Depth (mm)
1000	1000	17.79	52
1100	1000	17.79	54
1200	1000	17.79	55
1300	1000	17.79	56

The penetration depth of the steel plate is analyzed and observed after changing the density of the armor-piercing tracer, and the density is adjusted from 17.5 to 17.79 g/cm^3, 18 and 18.5 g/cm^3 through ANSYS finite element analysis. When the density of the tungsten rod increases, the penetration depth increases, and the results are shown in Table 4.

Table 4. Penetration depth with tungsten rod density.

Rate of Fire (m/s)	Distance (m)	Density (g/cm^3)	Penetration Depth (mm)
1306	1000	17.5	52
1306	1000	17.79	57
1306	1000	18	60
1306	1000	18.5	65

Taking a 25 mm-thick steel plate as an example, the influence of the incident angle is discussed. The inclination angle is defined as the angle α, the impact velocity of the armor-piercing projectile is set to 1306 m/s, and the inclination angle of the steel plate is set to 75, 60 and 45 degrees. As shown in Figure 3, when the angle of the steel plate is 45°, the armor-piercing projectile cannot penetrate completely through the steel plate; this angle is the extreme design angle.

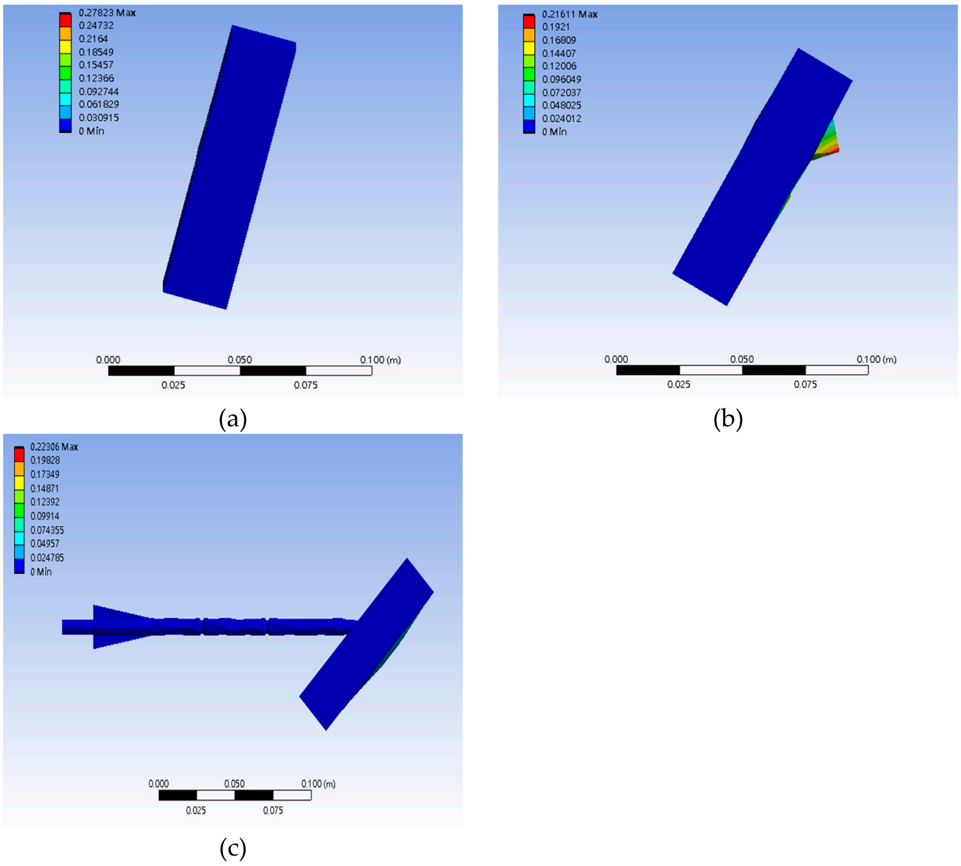


Figure 3. Effect of inclination angle. (**a**) Inclination: 75°; (**b**) inclination: 60°; (**c**) inclination: 45°.

4. Conclusions

In this study, an armor-piercing tracer with a 30 mm stabilized wing is developed. The software ANSYS Workbench is used for analysis. The density of the tungsten rod, the impact velocity, and the angle position of the steel plate designed for the armor-piercing tracer are analyzed by the Explicit Dynamics module. The test has led to the following conclusions.

1. Through numerical simulation analysis, we calculated the penetration depth of the steel plate at different impact speeds. The greater the impact speed, the greater the depth of the steel plate that can be penetrated.
2. The analysis of changing the density of the tungsten rod shows that the density of the tungsten rod increases, and the increased thickness of the armor-piercing tracer that can penetrate the steel plate increases.
3. By changing the design and installation angle of the steel plate under the stable firing muzzle velocity, the armor-piercing tracer cannot penetrate the steel plate and only causes a certain degree of damage around the surface of the steel plate when it is placed at an inclination of 45°. The steel plate can be penetrated only by firing at the same range of shooting points. The analysis and research data can be used for evaluation and reference by the developers of the subsequent design of armored vehicles.

Author Contributions: Conceptualization, Y.-S.W. and C.-H.H.; methodology, Y.-S.W.; software, Y.-S.W.; validation, Y.-S.W. and C.-H.H.; formal analysis, Y.-S.W.; investigation, Y.-S.W.; resources, C.-H.H.; data curation, Y.-S.W.; writing—original draft preparation, Y.-S.W.; writing—review and editing, C.-H.H.; visualization, Y.-S.W.; supervision, C.-H.H.; project administration, C.-H.H. and Y.-S.W. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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