RESEARCH ON THE INFLUENCE OF STRUCTURAL PARAMETERS OF FUME EXTRACTOR ON ITS PERFORMANCE ON THE TANK USING ANSYS FLUENT SOFTWARE

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ABSTRACT

This paper focuses on studying the influence of certain structural parameters of fume extractor on its performance of the 125mm smoothbore gun 2A46-M on the tank T90S. Using numerical methods, interior ballistics calculations for the gun are conducted to determine input parameters for the simulation. A simulation model of the gas extraction process for the fume extractor was developed using the module Fluent of the Ansys Workbench software. Based on this model, the study examines the effects of variables such as the number of intake-exhaust holes, the inclination angle of these holes, the installation position of the fume extractor, the size of the intake-exhaust holes, and the shape of the exhaust holes on their operational efficiency during firing. The results of the investigation provide essential reference parameters for calculating and designing fume extractors for the tank-mounted cannon of the tank T90S.

Keywords: *Fume extractor; intake-exhaust hole; Ansys Fluent; numerical simulation; artillery projectile.*

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1. INTRODUCTION

During the operation of a tank, after each shot a large amount of gunpowder gas accumulates in the fighting compartment, negatively affecting the crew's working capacity and health. Therefore, it is essential to implement measures to expel this gas from the fighting compartment to avoid these adverse effects. One potential solution is to use a fume extractor for the tank’s gun.

To study the fume extractor system for tank guns, various experimental parameters are required. There have been numerous studies on this subject conducted abroad. A notable example is the research by C.R. Woodley [1], who focused on developing a model of the gas suction and expulsion system for a fixed-valve-type fume extractor on a self-propelled gun, based on a 2D model of this component. The researcher used software tools to construct the model and evaluate the impact of several factors on the fume extractor's performance.

Woodley's study examined parameters such as the gas chamber volume, the installation position of the fume extractor, the locations of suction and exhaust holes, and the heat loss of gunpowder gas through the protective tube walls. The results showed that when the projectile passes the gas inlet hole, the gunpowder gas begins moving rapidly into the fume extractor, approximately 12 milliseconds after firing. At this point, the gas pressure inside the barrel reaches 120MPa. This high-pressure gas flows at a very large rate. When the pressure in the fume extractor reaches its peak, approximately 0.6MPa, the gas flow rate from the barrel through the suction hole into the smoke extractor is about 1,000kg/s, then gradually decreases. Once the projectile exits the barrel, the pressure in the barrel becomes lower than in the fume extractor, allowing the gas in the smoke extractor to be expelled. The total time from when the gas enters the smoke extractor to when the projectile leaves the barrel is 76 milliseconds.

Another study, conducted by Dr. Qing-Xiang Pei and Mr. Richard Foo [2], utilized Computational Fluid Dynamics (CFD) methods to model and simulate the gas suction and expulsion process of a valve-hole-type fume extractor. Using ANSYS Fluent software and supporting computational tools, the researchers evaluated and compared results with numerical methods. They developed a model describing the suction and expulsion process and investigated how certain structural parameters of the fume extractor influenced its operation. However, their study did not integrate the ballistic trajectory problem into the model development. In the work [3], the mathematical model which takes into account all of the main parameters influencing the pressure change inside the cylinder of the evacuator was developed. Differential equations that describe the flow field through the nozzle in the barrel wall and in the cylinder of the evacuator were solved numerically.

In Vietnam, research on fume extractors is still relatively new, with very few studies addressing this topic, especially those exploring in-depth how structural factors affect the fume extractor's performance. In the paper [4], the author only studies the effect of discharge nozzle number to the gas pressure in bore evacuator during discharging.

2. MATERIALS AND METHODS

Based on the parameters obtained after directly measuring the dimensions of the 125mm 2A46-M tank gun fume extractor on the tank T90S, the author created a 3D simulation of the fume extractor using SolidWorks. After obtaining the 3D model, it was integrated into the Ansys Workbench Fluent working environment.

In the fume extractor of cannon 2A46-M, the gas inlet and outlet are not separate. The gas inlet also serves as the gas outlet. However, for the Ansys Fluent software to function, separate inlet and outlet points are required. Therefore, the study assumes that the fume extractor has distinct gas inlet and outlet points, where the size of one gas inlet equals the total size of six gas outlet holes. The gas exhaust process begins immediately after the projectile base moves past the outlet. The 3D model of the fume extractor is described on the Fig. 1.

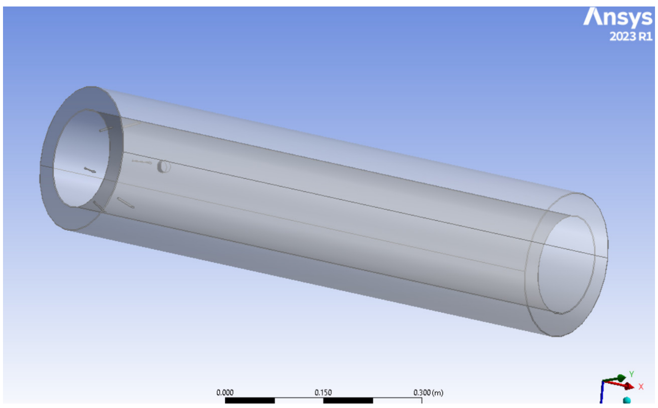

Fig. 1. 3D model of the fume extractor used for evaluation

The model includes six gas outlet holes, each with a diameter of 3mm, and one gas inlet hole with a diameter of 18mm.

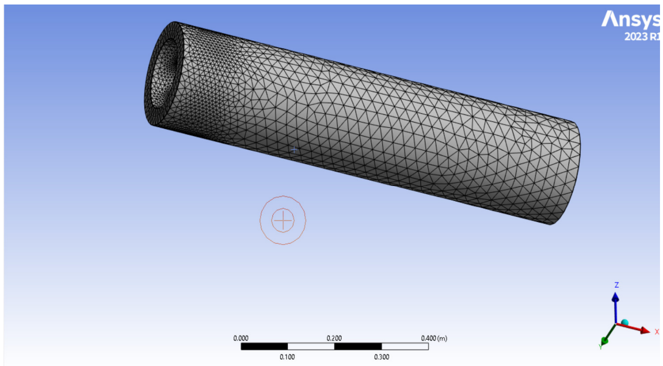

Fig. 2. Mesh model

The meshed model comprises 215,051 elements and 44,147 nodes. The total volume of the gas chamber in the model is 9221.44cm^3 (Fig. 2).

To investigate the impact of structural parameters on the performance of the fume extractor, building a computational model is essential. From the established model, structural parameters of the fume extractor are modified, and their effects on the device's performance are analyzed. The calculations and simulations were conducted using Ansys Workbench, specifically the module Fluent.

The study examines the effects of the following structural parameters on the performance of the fume extractor:

- Number of gas inlet/outlet holes.
- Angle of the gas inlet/outlet holes.
- Position of the fume extractor on the barrel.
- Dimensions of the gas inlet/outlet holes.
- Shape of the gas inlet/outlet holes.

3. RESULTS AND DISCUSSION

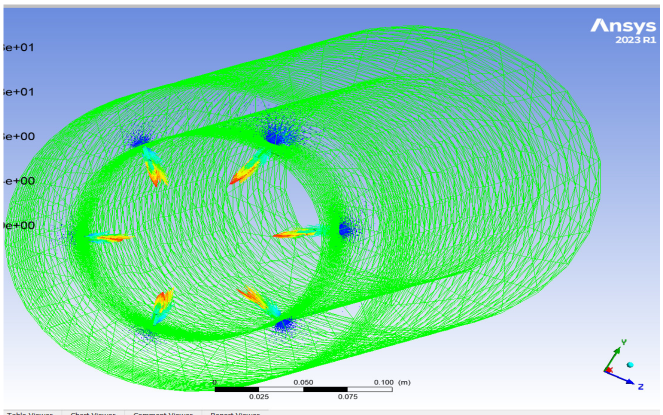

Fig. 3. Visualization of the gas exhaust process

Simulation results illustrating the gas exhaust process through the outlet holes using Ansys Fluent are shown in Fig. 3.

Impact of the number of outlet holes:

The investigation showed that after the projectile passes the gas inlet, the gunpowder gas fills the fume extractor chamber, and the gas pressure in the chamber gradually increases to a maximum before decreasing alongside the barrel pressure.

Specifically:

- The gas pressure in the chamber rises from 0 to a peak of 1466.95kg/cm^2 and then decreases to 1427.34kg/cm^2 within 0.085 seconds when there are two outlet holes.
- With six outlet holes, the pressure reduces further to 1347.6kg/cm^2, and 8.14% drop, achieving equilibrium with the barrel pressure as determined by internal ballistics.

Table 1. Effect of the number of outlet holes on pressure in the fume extractor

Number of outlets	Outlet pressure (kg/cm^2)	Pressure drop (%)
2	1427.34	2.7
4	1388.61	5.34
6	1347.6	8.14
8	1304.27	11.1

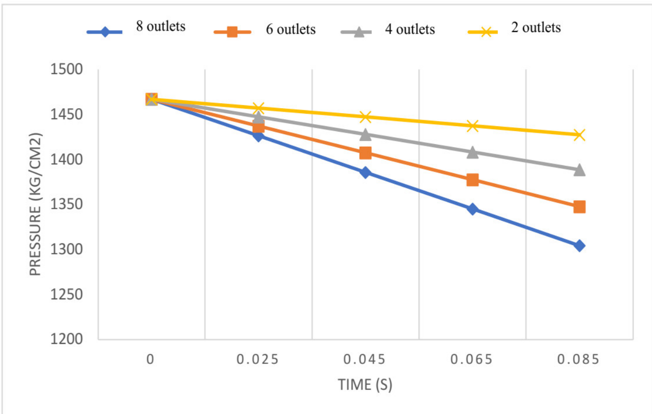

Fig. 4. Effect of the number of outlet holes on pressure in the fume extractor of the 125mm 2A46-M barrel

The study suggests that increasing the number of outlet holes improves the performance of the fume extractor. However, drilling additional holes negatively impacts the barrel's durability. In practice, the fume extractor of cannon 2A46-M has six outlet holes, balancing performance and durability to meet operational requirements.

Impact of outlet hole angle:

The investigation revealed that smaller outlet angles result in higher gas flow rates through the outlet holes, reaching a peak velocity of 14,935.1m/s and a flow rate of 0.6m^3/s at a 25° angle. However, smaller angles increase the length of the drilled hole, compromising the barrel's durability and manufacturing feasibility (Fig. 5).

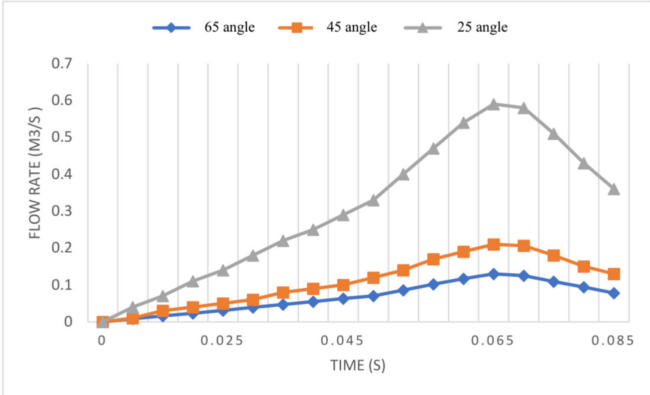

Fig. 5. Effect of outlet angle on gas flow rate

Impact of fume extractor position:

The study found that placing the fume extractor closer to the barrel's breech increases gas flow rates, shortening the suction-exhaust process. The highest flow rate of 0.7m^3/s was observed when the extractor was 2m from the breech, while the lowest flow rate of 0.4m^3/s was observed at 4m. However, closer placement increases the concentration of gunpowder residue and maintenance challenges (Fig. 6).

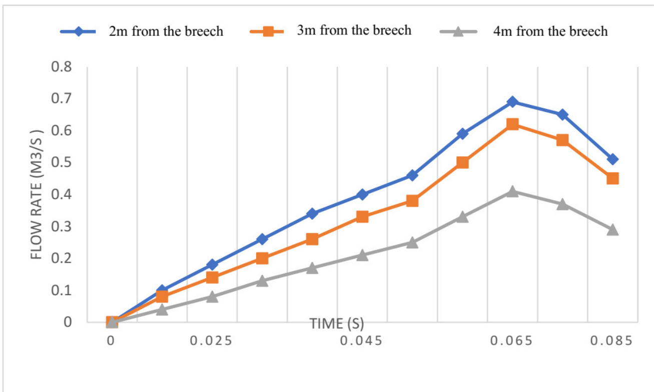

Fig. 6. Effect of smoke extractor position on gas flow rate

Impact of outlet hole size:

The study showed that larger outlet holes result in higher gas flow rates, with a peak flow rate of 1.64m^3/s at a 5mm outlet diameter. However, larger holes reduce barrel durability. The fume extractor of cannon 2A46-M has 3mm outlet holes, balancing performance and durability (Fig. 7).

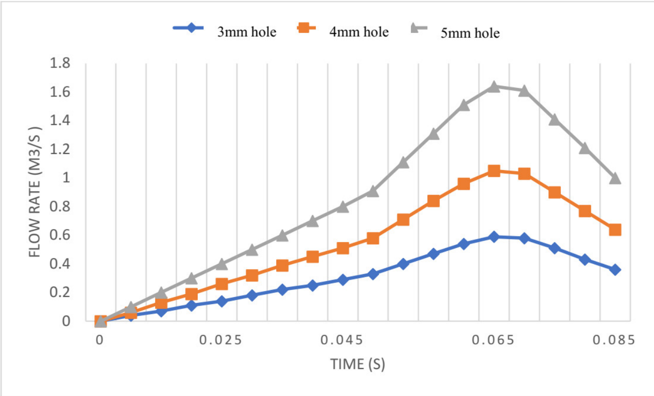

Fig. 7. Effect of outlet hole size on gas flow rate

Impact of outlet hole shape:

The study revealed that conical or funnel-shaped holes reduce gas velocity compared to cylindrical holes, prolonging the fume extractor's working duration. However, these shapes complicate manufacturing and compromise barrel durability. The original cylindrical design of fume extractor of the cannon 2A46-M remains optimal (Fig. 8).

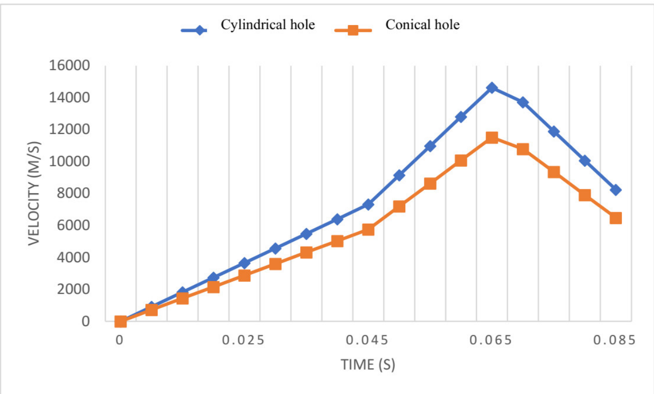

Fig. 8. Effect of outlet hole shape on gas velocity

4. CONCLUSION

The survey results indicate that the operation of the fume extractor for tank-mounted guns is significantly influenced by structural parameters. The most impactful factors include the number of exhaust holes, the angle of inclination of the exhaust holes, the position of the fume extractor, the size of the exhaust holes, and the shape of the exhaust holes.

Based on the findings, the study provides the following recommendations for the design and calculation of fume extraction systems for tank-mounted guns:

1. Increasing the number of exhaust holes improves efficiency, but too many holes can negatively affect the barrel's durability and lifespan.

2. Smaller exhaust hole angles enhance efficiency, but excessively small angles reduce the barrel's strength and complicate the machining process.

3. Placing the fume extractor closer to the breech of the barrel increases efficiency, but this positioning negatively impacts the technical condition and quality of the fume extractor while also increasing the risk of gunpowder gas diffusion back into the tank's combat compartment.

4. Larger exhaust hole sizes improve efficiency, but oversized holes compromise the barrel's strength and longevity.

5. Choosing cylindrical exhaust holes is the optimal solution, ensuring the fume extractor's effective operation, ease of manufacturing, and maintaining barrel durability.

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