

# Analysis of the formation of cavitation cavity during the movement of a modified bullet of 7.62x39 ammunition in a water environment

**Blagovest Bankov**

Department of „Armament and Technology for Design“  
National Military University “Vasil Levski”  
Shumen, Bulgaria  
blagovest.bankov@gmail.com

**Abstract.** The report examines the behavior of a 7.62x39 bullet in a water environment and the changes in the created cavitation cavity when the geometric and mass characteristics are altered. The studies are conducted through virtual prototypes and CFD (Computational Fluid Dynamics) analyses in a SolidWorks environment, with the density of the water around the projectile and the angle of the formed cavitation cavities being the control parameters. The results indicate that the placement of the radial slit channel in the middle of the ogive part yields the best results for the angle of the cavitation cavity, which helps reduce the friction forces on the projectile, thereby increasing its linear progression in a water environment.

**Keywords:** Cavitation, CFD Analysis, 7.62x39 projectile, SolidWorks

## I. INTRODUCTION

In today's dynamic development of the geopolitical situation and the emergence of various disturbances around the world, there is a need for rapid development of new weapon systems and ammunition that can be used in complex situations, such as military operations where there may be a need to strike targets at different distances, including those under the water surface.

One of the challenges facing ammunition manufacturers is the development of an economically viable projectile with enhanced linear-progressive motion in a water environment, to meet the needs of users.

It is known that when a solid body enters water, its dynamics are disrupted by the impact of external forces and moments in the water environment, which reduces its translational and rotational motion [1], [2], [3].

Thanks to the development of computer technologies and mathematical models over the last decades, manufacturers have the opportunity to create virtual

prototypes of future or existing products [4], [5] [6], which can be tested in a virtual environment. This also provides the possibility of rapid physical prototyping [7], [8], [9] of a series of projectiles with altered geometric and mass characteristics, to study their behavior in a water environment.

With the help of a developed approach for virtually investigating the change in the angle of the created cavitation cavity during the motion of modified 7.62x54 ammunition in the studies [10] and [11], it is possible to track how the geometric and mass changes of a 7.62x39 projectile moving in water could affect the created cavitation bubble.

Cavitation is a phenomenon that generates cavities that grow and break up during the process of fluid flow when the local pressure is lower than the saturated vapor pressure [12].

Fig. 1 presents a diagram of the cavitation cavities formed when a projectile penetrates a water medium.

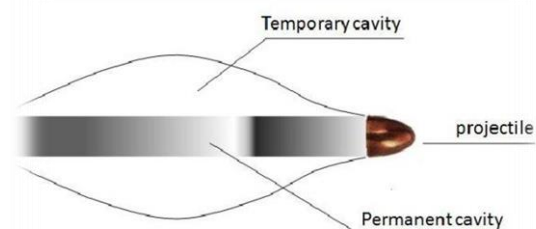


Fig. 1. Cavitation cavities [13].

The approach for studying the cavitation cavity, as used in this report, involves constructing a virtual model of the

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol4.8191>

© 2024 Blagovest Bankov. Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

bullet being researched and N number of variants with modified geometry, which consists of a slotted channel with a specific shape and dimensions in the ogive part of the projectile. The models are studied through CFD analysis, under the same conditions, and the formed angle between the bullet's axial line and a line starting from the ogive part of the bullet and ending at its base is compared. The slope is determined by an isoline showing the average water density zone (500 kg/m<sup>3</sup>) (Fig. 2), where it is considered that a cavitation cavity appears [14] [15] [16] [17].

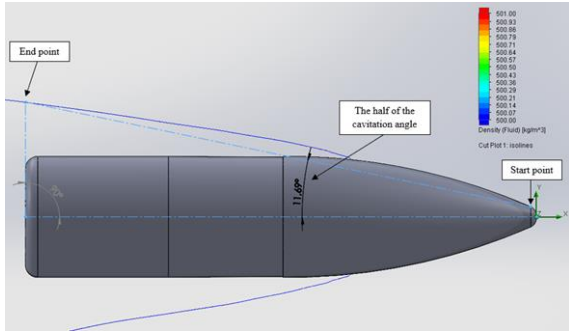


Fig. 2. Scheme of the study.

## II. MATERIALS AND METHODS

### A. Geometric modeling

The geometry of the projectile (Fig. 3) is designed based on a drawing with GRAU (system used by the Russian Armed Forces) index 57-N-231U, adopted in 1962 [18].

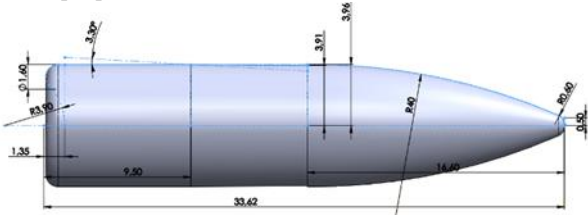


Fig. 3. The geometry of the projectile.

The shape and dimensions of the radially slotted channel of the bullets with altered geometric and mass characteristics are shown in Fig. 4, which are borrowed from the study [19], and the variations in its placement on the ogive part are shown in table 1.

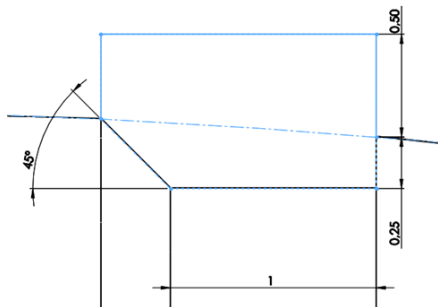


Fig. 4. The shape and dimensions of the radially slotted channel.

TABLE 1 VARIATIONS

Variation	1	2	3	4	5	6	7	8	9	10	11	12
Distance from top (mm)	0	3	4	5	6	7	8	9	10	11	12	13

Fig. 5 shows two variations of the projectile - (a) without a channel and (b) with a slotted channel.

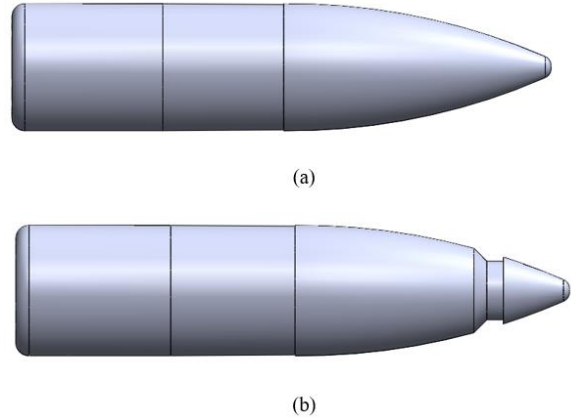


Fig. 5. Virtual models.

### B. Mesh model

The studied area is shown in Fig. 6, where the approach of constructing a 2D analysis is adopted due to the presence of rotational symmetry in the examined body. The number of finite elements in the studied area is 2024.

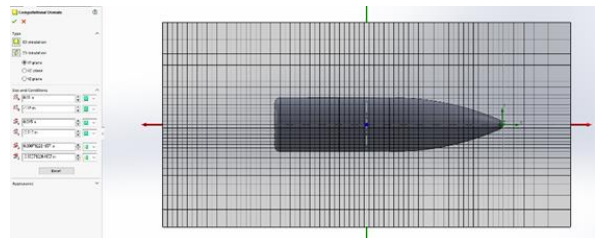


Fig. 6. The studied area.

### C. Input data

The following input data have been introduced for conducting the analysis:

- *Velocity* – the projectile's speed is assumed to be 715 m/s, corresponding to the initial velocity measured at 30 cm from the muzzle of the AKM-47 rifle [20];
- *Angular velocity* – the rotation speed is calculated using equation (1), which considers the rifling pitch in the barrel [21].

$$\omega_d = \pi \frac{V_d}{30S}, [s^{-1}], \quad (1)$$

where:

$V_d$  – translational velocity of the bullet [m/s];

$S$  – the rifling pitch in the barrel [m].

- *Dissolved gas mass fraction* – calculated with an equation (2) [19].

$$\sigma = 2 \frac{(P-P_0)}{\rho V^2} \quad (2)$$

where:

$P$  – atmospheric pressure at a temperature of 20°C [Pa];

$P_0$  – the pressure of the water vapor in the cavity (the approximate pressure is 0.02 atm [19]) [Pa];

$\rho$  – the density of water at a temperature of 20°C [kg/m<sup>3</sup>];

$V$  – the velocity of the projectile [m/s].

- *Turbulence Parameters* – turbulence intensity and length scale were calculated based on the length and speed of the projectile, and the kinematic viscosity of water, using the k-Epsilon model.

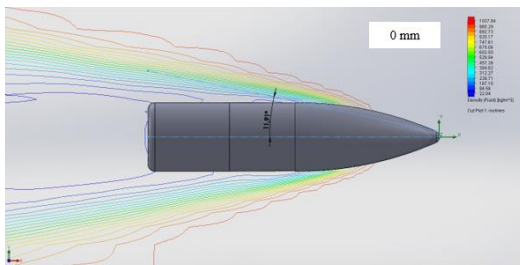
The input data introduced are shown in table 2.

TABLE 2 INPUT DATA

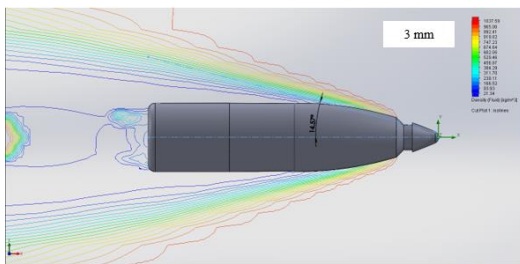
Parameter	Value	Dimension
Velocity	715	m/s
Angular velocity	32,67	rad/s
Dissolved gas mass fraction	0,000423099227	-
Temperature	293,2	K
Pressure	101325	Pa
Turbulence intensity	0,02552	%
Turbulence length	0,000234	m

### III. RESULTS AND DISCUSSION

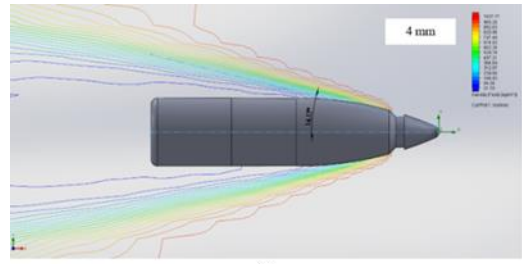
In Fig. 7 and Fig. 8, the results of the studies are presented graphically, showing the angles of the formed cavitation cavities, and in Fig. 9 all the obtained angles are compared, demonstrating that the best results are achieved when the slotted channel is positioned 7 mm from the tip of the bullet.



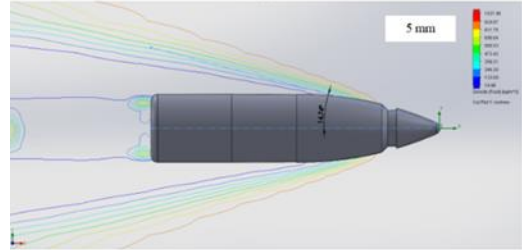
(a)



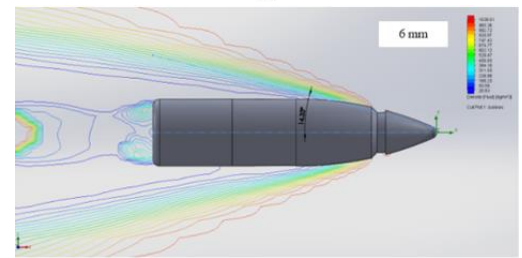
(b)



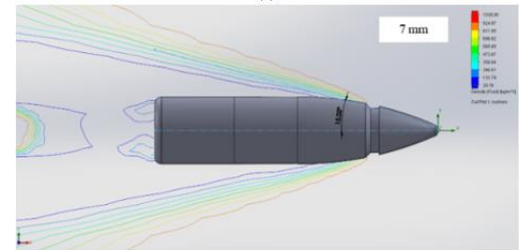
(c)



(d)

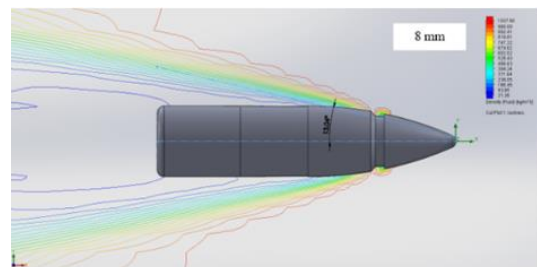


(e)

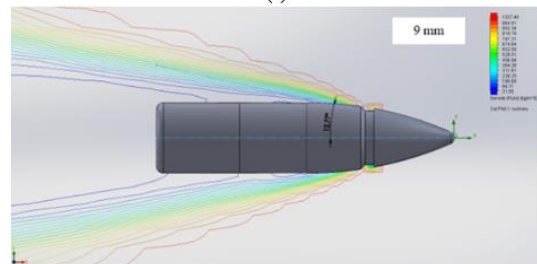


(f)

Fig. 7. Result - first part.



(a)



(b)

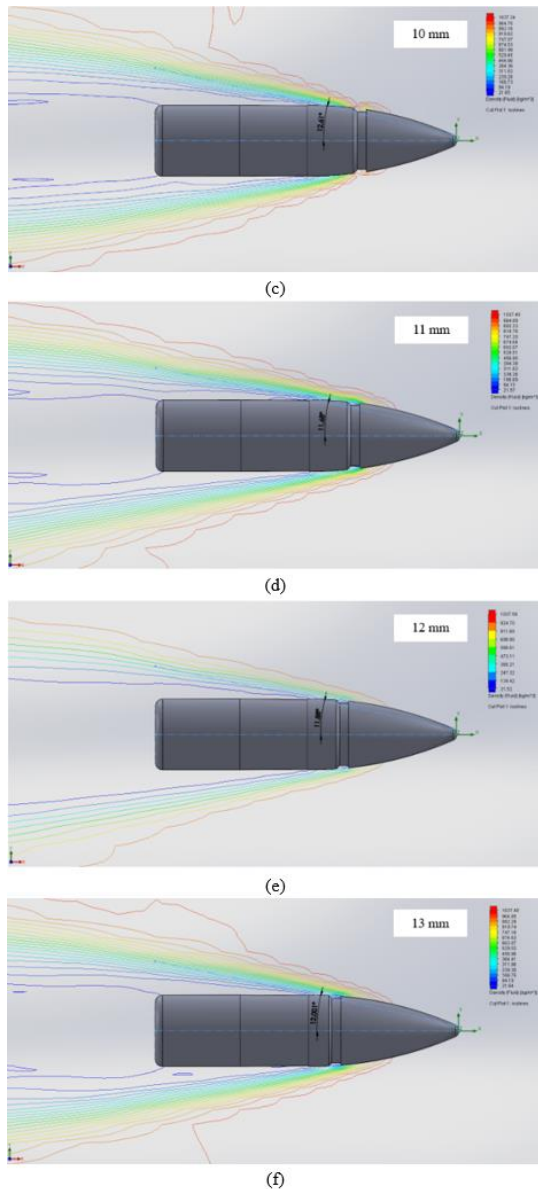


Fig. 8. Result - second part.

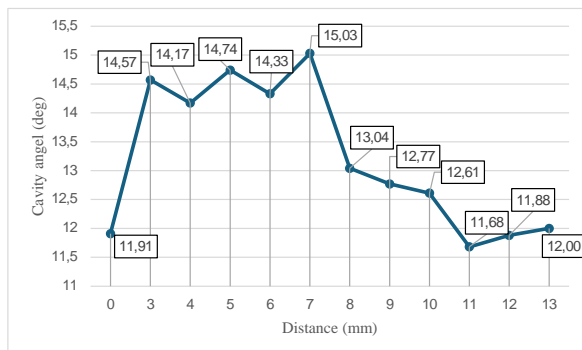


Fig. 9. The angle of the cavitation cavity vs. notch the distance from the tip of the bullet.

#### IV. CONCLUSION

- The study found that the placement of the slit channel near the middle of the live part yields the best results for the angle of the cavitation cavity, which would help reduce the forces negatively affecting the dynamics

of the projectile, thereby extending its translational movement in a water medium.

- The results from positioning the cut more than 10 mm from the tip of the bullet are approximately the same as those of the projectile without a radial cut.
- Thanks to virtual prototyping, it is possible to analyze various projectile variations with changed geometry and mass characteristics, which in turn accelerates the process of developing new ammunition.

#### ACKNOWLEDGMENTS

The report is being carried out under the National Scientific Program "Security and Defense," adopted by Council of Ministers Decree № 731 of October 21, 2021, and in accordance with Agreement № D01-74/19.05.2022.



#### REFERENCES

- V.-T. Nguyen, T.-H. Phan, and W.-G. Park, 'Modeling and numerical simulation of ricochet and penetration of water entry bodies using an efficient free surface model', *International Journal of Mechanical Sciences*, vol. 182, p. 105726, Sep. 2020, doi: 10.1016/j.ijmecsci.2020.105726.
- S. Liu, C. Xu, Y. Wen, S. Wang, J. Zhou, and X. Zhou, 'Cavity dynamics in 10 wt% gelatin penetration of rifle bullet', *International Journal of Impact Engineering*, vol. 122, pp. 296–304, Dec. 2018, doi: 10.1016/j.ijimpeng.2018.09.006.
- G.-X. Yan, G. Pan, Y. Shi, L.-M. Chao, and D. Zhang, 'Experimental and numerical investigation of water impact on air-launched AUVs', *Ocean Engineering*, vol. 167, pp. 156–168, Nov. 2018, doi: 10.1016/j.oceaneng.2018.08.044.
- Y. Sofronov, M. Zagorski, G. Todorov, and T. Gavrilov, 'Approach for reverse engineering of complex geometry components', presented at the *BulTrans*, Sozopol, Bulgaria, 2019.
- S. Antonov, 'Modern technologies in computer design and application of systems for stress-strain calculations of weapon system elements', presented at the *International Conference knowledge-based organization*, 2020.
- K. Lukaszewicz, 'Use of CAD Software in the Process of Virtual Prototyping of Machinery', *Procedia Engineering*, vol. 182, pp. 425–433, 2017, doi: 10.1016/j.proeng.2017.03.127.
- Y.-M. Huang and H.-Y. Lan, 'CAD/CAE/CAM integration for increasing the accuracy of mask rapid prototyping system', *Computers in Industry*, vol. 56, no. 5, pp. 442–456, Jun. 2005, doi: 10.1016/j.compind.2005.01.002.
- A. Fischer, 'Multi-level models for reverse engineering and rapid prototyping in remote CAD systems', *Computer-Aided Design*, vol. 32, no. 1, pp. 27–38, Jan. 2000, doi: 10.1016/S0010-4485(99)00081-0.
- K. Subburaj, C. Nair, S. Rajesh, S. M. Meshram, and B. Ravi, 'Rapid development of auricular prosthesis using CAD and rapid prototyping technologies', *International Journal of Oral and Maxillofacial Surgery*, vol. 36, no. 10, pp. 938–943, Oct. 2007, doi: 10.1016/j.ijom.2007.07.013.
- V. Ganev, R. Lazarov, and B. Bankov, 'Approach for determining the ballistic characteristics of the ammunition', presented at the *International Scientific Conference —Defense Technologies*, Shumen, 2023, pp. 285–289.
- V. Ganev and B. Bankov, 'Investigation of the motion of a 7,62x54 caliber projectile in an aquatic environment', presented at the *Актуални проблеми на сигурността*, Велико Търново: Издателски комплекс на НВУ „Васил Левски“, 2023, pp. 1511–1516.
- H. Fang and M. Duan, 'Special Problems of Deep-Sea Oil and Gas Engineering', in *Offshore Operation Facilities*, Elsevier, 2014, pp. 537–686. doi: 10.1016/B978-0-12-396977-4.00004-4.
- P. Lichte, R. Oberbeck, M. Binnebösel, R. Wildenauer, H.-C. Pape, and P. Kobbe, 'A civilian perspective on ballistic trauma and gunshot



- injuries', *Scand J Trauma Resusc Emerg Med*, vol. 18, no. 1, p. 35, 2010, doi: 10.1186/1757-7241-18-35.
- [14] F. Magaletti, M. Gallo, and C. M. Casciola, 'Water cavitation from ambient to high temperatures', *Sci Rep*, vol. 11, no. 1, p. 20801, Oct. 2021, doi: 10.1038/s41598-021-99863-z.
- [15] F. Caupin and E. Herbert, 'Cavitation in water: a review', *Comptes Rendus Physique*, vol. 7, no. 9–10, pp. 1000–1017, Nov. 2006, doi: 10.1016/j.crhy.2006.10.015.
- [16] C. E. Brennen, *Cavitation and Bubble Dynamics*. Cambridge: Cambridge University Press, 2013. doi: 10.1017/CBO9781107338760.
- [17] D. H. Trevena, 'Cavitation and the generation of tension in liquids', *J. Phys. D: Appl. Phys.*, vol. 17, no. 11, pp. 2139–2164, Nov. 1984, doi: 10.1088/0022-3727/17/11/003.
- [18] EOD, '7.62x39 green black tip factory 711', International Ammunition Association, Inc. Accessed: Jan. 05, 2024. [Online]. Available: <https://forum.cartridgecollectors.org/t/7-62x39-green-black-tip-factory-711/38421>
- [19] Р. Лазаров, 'Изследване на влиянието на формата на куршума върху рикошетното му действие', НВУ 'Васил Левски', Велико Търново, 2022.
- [20] Министерство на народната отбрана, *Наставление по стрелково дело. Материална част на стрелково оръжие*. София: Военно издателство, 1987.
- [21] Я. Димитрова, 'Изследване на влиянието на трибологичните характеристики на шумозаглушител върху групраността при стрелба със стрелково оръжие.', НВУ "Васил Левски", Велико Търново, 2021.