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Analysis of the influence of the ogive radius of a 7.62x39 ammunition bullet on the cavitation cavity

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***Abstract*. The aim of the current study is to examine the impact of the ogive radius of a 7.62x39 ammunition projectile on the positioning of a radially-slotted channel that helps increase the angle of the cavitation cavity. The studies were conducted using CFD (Computational Fluid Dynamics) analyses in a SolidWorks environment, simulating the projectile's movement in a water environment. The research findings indicate that lower values of the ogive radius result in higher values of the cavitation cavity angle, which in turn suggests that lower values are more favorable for creating bullets with slotted channels, which enhances linear-progressive movement in a water environment and thus increases the chance of hitting targets below sea level.**

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

I. INTRODUCTION

Through the development of computing power, various mathematical models, and software products for virtual prototyping and research, there is an opportunity for faster analysis of problems of any nature. The possibility of designing future and existing products using Reverse Engineering techniques and the assistance of various CAD (Computer Aided Design) software products in a virtual environment opens potential directions for the development of products from a wide range of fields [1] [2] [3] [4] [5] [6] [7] [8] [9] [10].

Apart from the broad and well-known industry, design and analysis software is also used for creating weapon systems, as well as for developing new types of ammunition. One of the issues considered in the military industry is increasing the range of bullets in a water medium.

When a solid body enters a water medium, its dynamics are disrupted due to various forces, significantly reducing its movement [11] [12] [13] [14]. It is also known that when a solid body moves at a sufficiently high speed under water, pressure around the body itself is created, which is lower than the pressure of the saturated steam in the surrounding water, thus forming a cavity that can encompass a large part of the body. When super cavitation occurs, only a small part of the body is in contact with the steam and the formed cavity [15] [16] [17] [18] [19] [20].

The use of specialized software products for virtual analyses, collectively known as “Computer Aided Engineering” (CAE), and specifically those allowing fluid analyses (CFD, Computational Fluid Dynamics), enable manufacturers, researchers, and designers to study various processes [21] [22] [23] [24] [25], such as cavitation, thereby improving existing products or producing new prototypes [26] [27].

With the help of a developed method using CFD analysis for virtual study of the change in the angle of the created cavitation cavity during the movement of a modified projectile of ammunition 7.62x54, shown in the studies [28] and [29], it is possible to examine the influence of the ogive radius of a 7.62x39 bullet on the angle of the cavitation cavity, as well as on the positioning of a radially slotted channel, which aims to increase the values of the cavity angle.

The approach consists in designing n number of virtual models, which are subjected to identical input data and the resulting angle of the cavitation cavity is examined, which is measured by the angle formed between two lines - the axial line of the projectile and a line starting from the ogive part of the bullet and ending at its base, where the slope is determined by an isoline, showing the average water density zone (500 kg/m3) (Fig. 1), at which it is considered that a cavitation cavity appears [16] [17] [18] [19].

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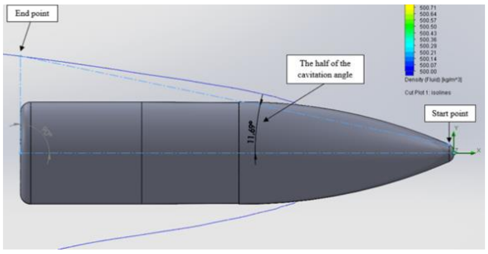
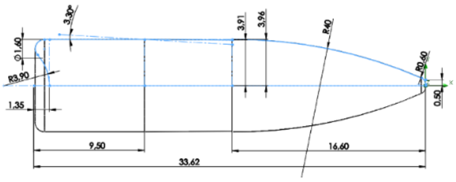


Fig. 1. Scheme of the study.

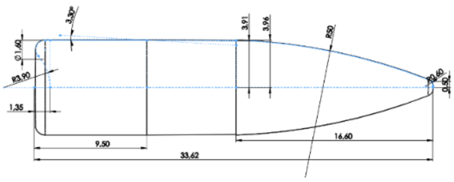
II. Materials and Methods

A. Geometric modeling

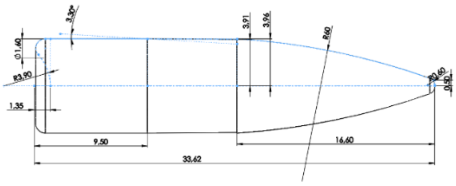
Virtual prototypes of a 7.62x39 mm ammunition projectile with various ogive radii, ranging from R40 to R80, have been designed (Fig. 2).



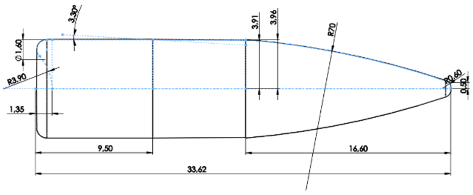
(a) R40



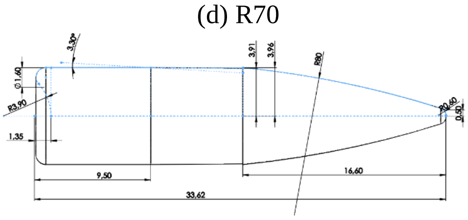
(b) R50



(c) R60



(d) R70



(e) R80

Fig. 2. Geometric models.

The shape and dimensions of the radially slotted channel are shown in Fig. 3, as they are adopted from the work [30].

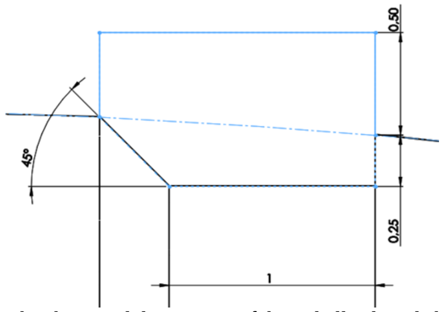


Fig. 3. The shape and dimensions of the radially slotted channel.

B. Mesh model

A two-dimensional finite element mesh model has been constructed due to the rotational symmetry of the body under study. The model consists of 2024 finite elements (Fig. 4). An approach with an adaptive mesh has been chosen, with a Ratio Factor of 3.5 for densifying the mesh around the ogive and the radially slotted channel.

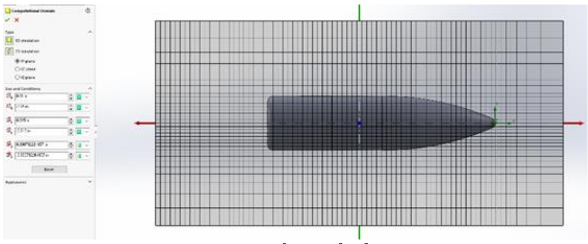


Fig. 4. The studied area.

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 [31];
- *Angular velocity* – the rotation speed is calculated using equation (1), which considers the rifling pitch in the barrel [32].

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

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).

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

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 [30]) [Pa];

ρ – the density of water at a temperature of 20°C [kg/m^3];

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

- *Turbulence intensity* - this parameter is calculated based on the k-Epsilon model using equation (3).

$$TI = \frac{\sqrt{\frac{2}{3}k}}{U}, \quad (3)$$

where:

U - the average velocity of the fluid [m/s];

k - the turbulent kinetic energy per unit volume, which within the k-Epsilon model is determined relative to the length of the body (in this case, the bullet), the velocity of the fluid, and the kinematic viscosity of the fluid.

- *Length scale* - The value is calculated based on equation (4).

$$LC = C_\mu \frac{k^{\frac{2}{3}}}{\epsilon}, \tag{4}$$

where:

C_μ - is the constant in the k-Epsilon model and has a value of 0.09 [33];

k - the turbulent kinetic energy per unit volume;

ϵ - the rate of dissipation, whose approximate value can be found using formula (5).

$$\epsilon \approx \frac{V^3}{L} \tag{5}$$

where:
V – fluid velocity [m/s];
L – length of the body [m]
The summarized input data can be seen in table 1.

TABLE 1 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. 5, a diagram is shown that compares the results from all the analyses of the angles of the cavitation cavity, and in table 2, their numerical values are provided.

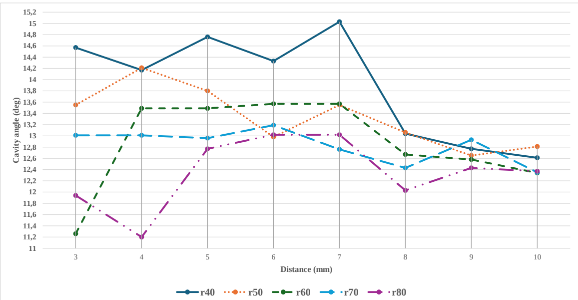


Fig. 5. The angle of the cavitation cavity vs. notch the distance from the tips of the bullets.

In the conducted analyses, a trend of decreasing the angle of the cavitation cavity was observed with the increase in the ogive radius. Upon closer examination of the section with the radially slotted channel at 7mm from the tip of the projectile, in the models with radii r40 and r80, it was found that the lower radius creates higher fluid vortices in the channel (Fig. 6) in zone 1 (Fig. 7).

TABLE 2 THE CAVITY CAVITIES ANGLES

R / mm	R40	R50	R60	R70	R80
3	14,57	13,55	11,26	13,01	11,94
4	14,17	14,21	13,49	13,01	11,20
5	14,76	13,8	13,49	12,96	12,77
6	14,33	12,98	13,57	13,19	13,02
7	15,03	13,55	13,57	12,76	13,02
8	13,04	13,06	12,67	12,43	12,03
9	12,77	12,65	12,58	12,93	12,43
10	12,61	12,81	12,34	12,35	12,37

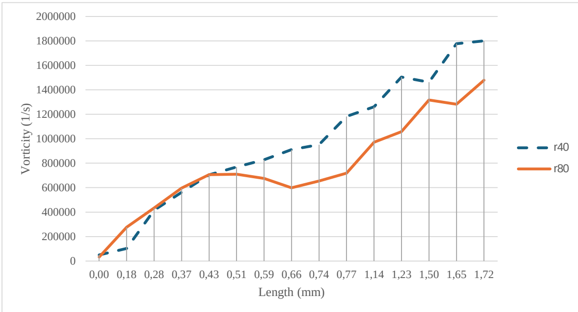


Fig. 6. Vorticity.

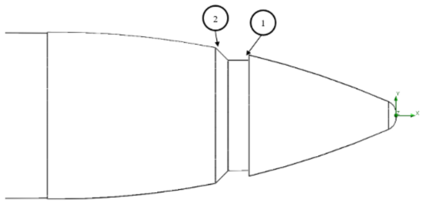


Fig. 7. Considered areas.

When examining the pressure in the same section, a lower pressure is observed in the model with a 40 mm radius (Fig. 8), where in zone 2 it increases by nearly 20 MPa, which could be attributed to the vortices that have formed.

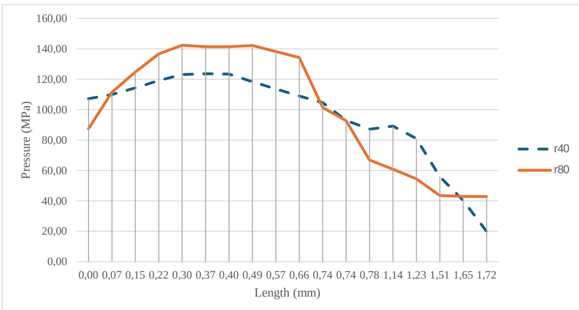


Fig. 8. Pressure results.

The fluid density in zones 1 and 2 has also been examined, with lower values observed in the model with an ogive of r40 (Fig. 9).

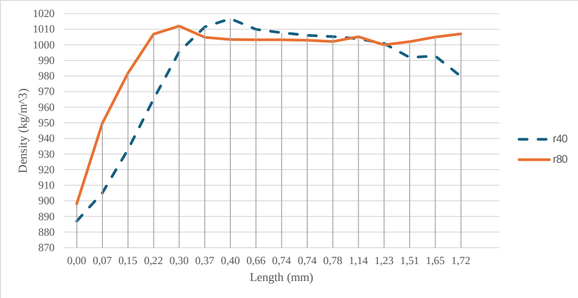


Fig. 9. Density results.

IV. CONCLUSION

- Radial channels that are 8 mm and above are less efficient in creating a cavitation cavity.
- The most suitable positioning of radial channels along the ogive part is in the area from 5 to 7 mm from the tip of the bullet.
- Approximately 10% better values are observed with the ogive of r40 when the radial channel is positioned between 5 and 7 mm compared to the same positioning but with an ogive radius of r60 to r80.
- Additional research on a projectile with an ogive radius of 40 mm and a projectile with a radius of 80 mm confirms the hypothesis that lower values of the ogive radius influence the nature of the cavitation cavity, and the creation of radial slotted channels in the middle zone of the ogive facilitates its expansion.

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