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Modernizing Naval Anti-Aircraft Projectiles: Design and Simulation

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Abstract. This paper explores the modernization of ammunition for naval artillery installations, focusing on adapting AK 630-gun projectiles to advanced AHEAD technology, similar to that used by the Oerlikon Millennium Gun. Through 3D modeling in the Fusion 360 and dynamic simulations in ANSYS, the study presents a detailed design of the new projectile, including the integration of piercing fragment and an innovative detonation control system. The results of the simulations demonstrate the projectile's improved ability to effectively engage air targets or surface drones (USVs).

Keywords: *Naval Artillery Modernization, AHEAD Technology Integration, 3D Projectile Modeling,, Anti-Aircraft Munitions.*

1. Introduction

In the context of technological evolution and threats in the contemporary maritime environment, modernization and improvement of warship capabilities become an essential necessity. A first step may be to modernise naval artillery installations or ammunition related to such installations.[1], [2], [3]

Each type of naval artillery installation uses a certain ammunition depending on the caliber of the installation's barrel and the specific fire missions it performs.[1], [4]

The caliber represents the inner diameter of the barrel but also specifies the diameter of the projectile. The caliber of naval projectiles for rifled barreled artillery installations shall be determined by measuring the distance between two grooves.

The small caliber of naval projectiles used for artillery installations ranges in diameter from 20 mm to 76 mm. The most representative calibers for this category are: 20 mm, 23 mm, 25 mm, 30 mm, 37 mm, 40 mm, 45 mm, 45 mm, 57 mm, 60 mm and 75 mm.

In terms of air defence (AAW), small-caliber anti-aircraft artillery installations are used, such as[5], [6], [7]:

- Oerlikon Millennium Gun
- Naval Artillery Installation – AK-630
- Goalkeeper

This paper deals with the possibility of modifying the classic ammunition of the AK 630 gun (*AO18 – d30×165mm* – Fig. 1) after the projectile model used by the Oerlikon Millennium Gun (AHEAD projectile, with shrapnel – Fig. 2 and Fig. 3). This study involves drawing the new type of projectile using the Fusion 360 program, simulating the explosion using ANSYS software and making the 3D model of the projectile.[1], [4], [8], [9]

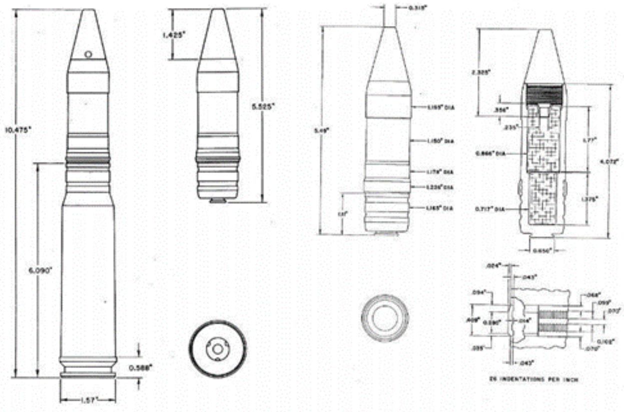

Fig. 1 – Sketch of an AO18 projectile – 30×165mm

Fig. 2 – AHEAD projectile

Fig. 3 – AHEAD ammunition

2. Projectile modeling in FUSION 360 software

Fusion 360 is a 3D based modelling software, capable of modelling, simulation, and documentation. It was developed by Autodesk in 2013 and is a cloud-based system with a top-down approach. This means that it allows the users to create larger structures, which are then broken down into smaller components.[10]

Starting from fig. 1, we proceeded to drawing the projectile corresponding to the AK 630 naval artillery installation. (Fig. 4). We started drawing the new projectile in the OY plane, to make the sketch we used the Design extension with the Create Sketch function, so we managed to make the sketch for the outside of the tip, body and cartridge tube for 3D modeling. To achieve 3D modeling of the exterior parts, the Revolve function from the Surface menu was used.[10]

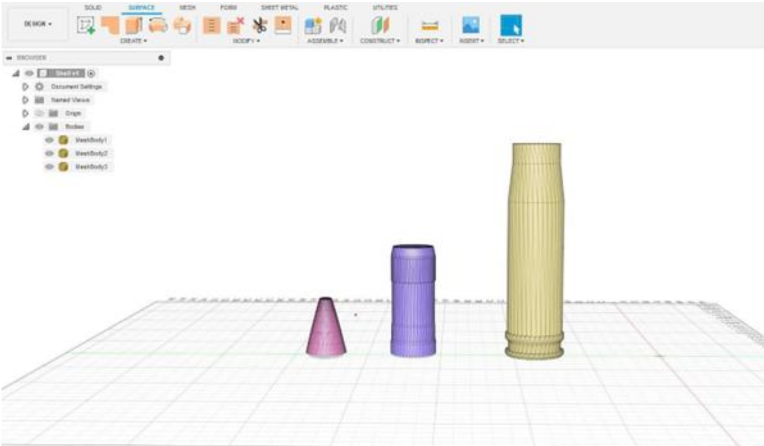

Fig. 4 – 3D modeling of the exterior of the AO18 projectile - 30×165mm

In Figure 4 it can be seen that the component parts already have the Mesh function applied, which has been set to 10 mm for a more accurate detailing of surfaces and for a successful design without imperfections.

Next, for the realization of the interior components and the most important point in order to modernize and implement this type of projectile, the Inspect function was used to accurately measure the space in which we are allowed to implement the 150 piercing fragment and the shrapnel burst detonation control system.

Thus, having in front of the image of the components, it was realized that in the previous idea the sketch of each part separately, grouping the 150 rods in columns of 5 groups of shrapnel and the placement of the detonation control system was placed exactly like a fuse, the lower part being inside the cartridge tube, thus becoming the base of the projectile itself and the upper one inside the body at a permissive distance of 4 mm from the 150 shrapnel, thus having the minimum space required to perform the detonation (Fig. 5).

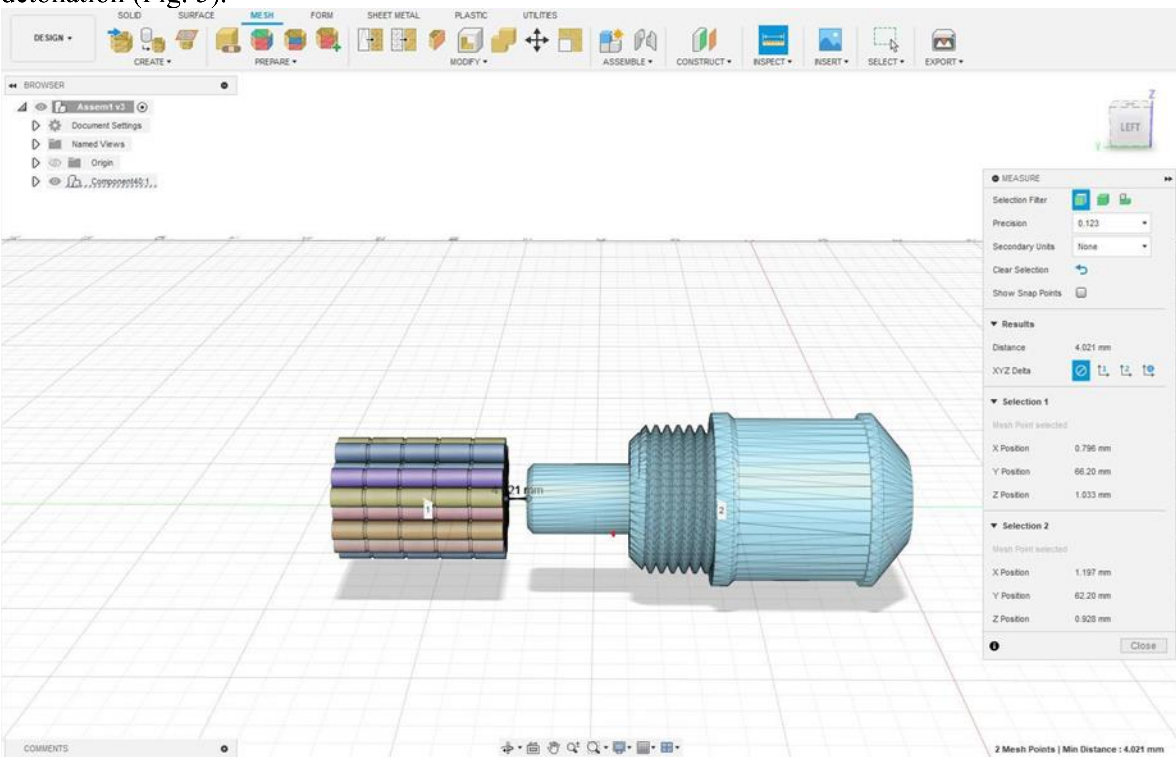

Fig. 5 – 3D modeling of interior parts

The next step, and the one that half validates the fact that an exact design has been made, is to assemble all the component parts into a ready-to-use projectile, so the Assemble function from the program's Solid menu was initially used, adding that all components have a tolerance of 0.1 mm when assembling.

For a better perspective of the result, we returned to the Mesh menu where the Assemble function was used to better visualize the joint details and avoid possible gaps that could affect the characteristics and aerodynamics of the projectile.

3. Validation of 3D modelling using ANSYS software

ANSYS is simulation software used in engineering to model and analyze the behavior of various systems. A simulation in ANSYS involves creating a virtual model of a system, such as a part, assembly or entire product, and applying specific conditions and loads to evaluate system performance under various operating conditions.[11]

For a more accurate and realistic visualization of what happens to the projectile in the simulation, the simulation type Explicit Dynamics was used (Fig. 6.) because it means an analysis method to model and evaluate the behavior of systems under extreme dynamic loads and conditions. This type of analysis focuses on the study of the behavior of systems where inertia and inherent effects are very important and cannot be neglected. The Explicit Dynamics method is based on dividing time into small steps, in which the movement and response of the system to the applied forces and loads are explicitly calculated.[11]

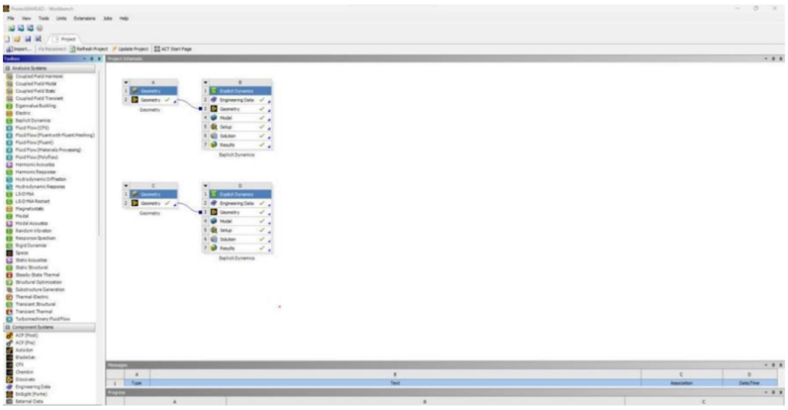

Fig. 6 – Structural simulation interface

In order to carry out the simulation, we started by importing the geometry and inspecting each element for error checking. (Fig. 7)

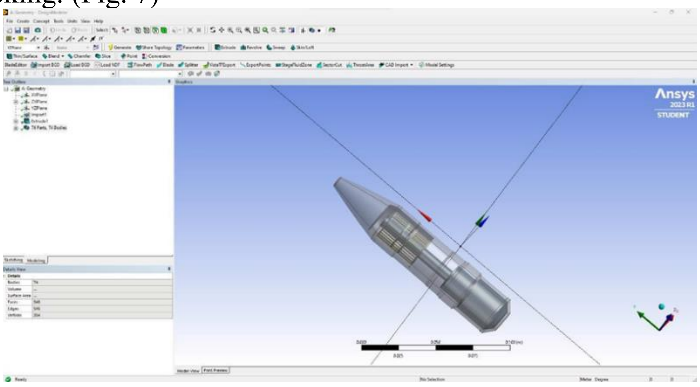

Fig.7 – Import and inspection of geometries

So we want to see how the AO18 30 × 165mm projectile of AHEAD type reacts, in a space where the friction force with air is neglected and the projectile is printed a speed of 1020 m / s and a rotational speed of 5000 rads / s (this speed is necessary because the simulation is run in 2×10-4 s Since processing more seconds would mean hundreds of hours of waiting and processing errors), at the base of the projectile it has a rotational speed of 2.09 rad/s. It was introduced that the projectile is a rigid whose body is produced from high-carbon steel. (Fig. 8) This type of steel has superior mechanical properties, such as strength and durability, which make it suitable for use in projectiles of this type. In the engineer's library provided by ANSYS we have this material under the name of AISI 1095, the density of the material increases its hardness, having a density of 7.85 $g / c\ m3$.

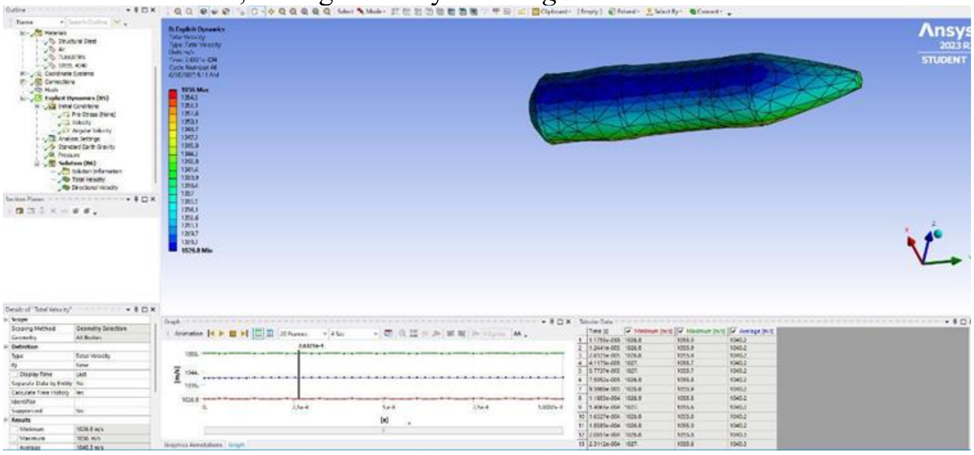

Fig. 8 – simulation of projectile velocity

In Fig. 9 and Fig. 10 they present the mode of action of the new type of anti-aircraft projectile: the explosion of the projectile when approaching the target, the scattering of shrapnel and subsequently the penetration of the target's body. In this step it was used in the Setup function to introduce forces and conditions, so we have a velocity of 1020 m/s for the projectile body. The gravitational acceleration present in the simulation environment with the value of 9,805 m/s2 was also implemented. At the end of the settings and force input, the detonation point was set at the top of the detonation control device and the initiation of detonations was set at a distance of 0.5 m from the target.

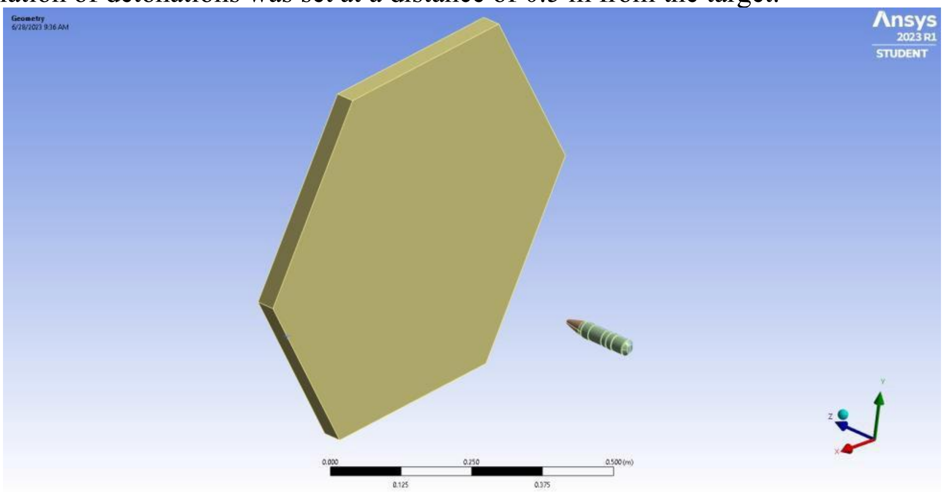

Fig. 9 – Geometry of target effect simulation

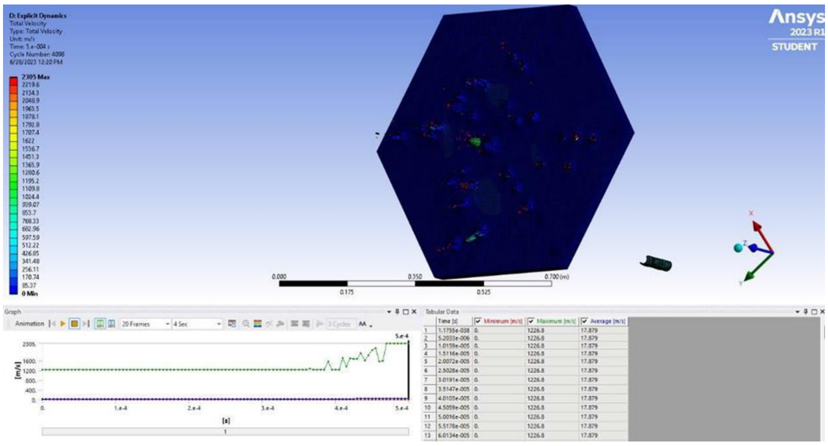

Fig.10 – Target effect

The ANSYS simulation of the AHEAD projectile demonstrates its effectiveness in anti-aircraft scenarios, reflecting an optimal combination of speed, precision and destructive power. The ability to maintain stability at extremely high speeds and rotations, together with an effective response to detonation close to the target, underlines the technological superiority of the projectile.

4. Conclusions

This work demonstrates the significant potential of modernizing naval munitions by adopting advanced technologies, such as AHEAD technology, in classic AK 630 artillery installation projectiles. Through 3D modeling and dynamic simulations conducted in Fusion 360 and ANSYS, the study highlights the viability and effectiveness of proposed improvements. The implementation of shrapnel and a detonation control system enriches the defensive arsenal against air targets (helicopters, aircraft, missiles, drones). This approach not only responds to today's maritime security needs, but also opens up new horizons for innovations in artillery ammunition. The modernization of the AO18 projectile, by incorporating the characteristics of the AHEAD projectile, represents a step towards improving the air defense capabilities of military vessels; The new type of ammunition can also be used to combat aerial drones or surface drones.

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