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DESIGN AND MANUFACTURING PROCESS FOR A BALLISTIC MISSILE

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ABSTRACT:

Designing a ballistic missile flight depends on the mission and the stress to which the missile is subject. Missile's requests are determined by: the organization of components; flight regime type, engine configuration and aerodynamic performance of the rocket flight. In this paper has been developed a ballistic missile with a smooth fuselage type, 10 control surfaces, 8 directional surfaces for cornering execution, 2 for maneuvers of execution to change the angle of incidence and 4 stabilizers direction. Through the technology of gluing and clamping of the shell and the use of titanium components, mass of ballistic missile presented a significant decrease in weight and a structure with high strength.

KEYWORDS:

Design, ballistic missile, propulsion system, manufacturing technologies

1. Introduction

A ballistic missile is a missile that follows a predetermined trajectory, aimed at delivering to the chosen target of warheads destruction. Air-to-air missiles have cylindrical form, relatively small diameter and long length with the purpose to minimize the friction occurring in their range of high speed. (Carter & Schwartz, 1984). Construction of the missiles can be divided into 5 main systems (Figure no. 1):

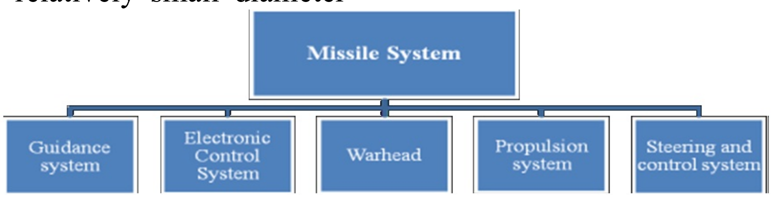

Figure no. 1. Base systems of the missiles

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The front of the missile contains the guidance system, composed of either a radar system, an electro-optical or infrared detector. The next part typically contains the warhead, usually in the centre of the racket, containing a greater mass of explosives, surrounded by metal shavings scraped for stronger target damage.

Obviously, in the back of the rocket propulsion system is positioned the propulsion system with its own control system. Most rockets use rocket engines with solid fuel, but some long-range missiles use engines with liquid fuel which gives them fuel storage capacity to execute certain final maneuvers before striking down the target or to position itself on the best path for striking down the target, this are energy and fuel consuming maneuvers. Instead there are missiles with solid fuel which execute maneuvers during evolution, but these uses a second missile engine which starts during the execution maneuvers (Gansler, 2010). Steering and control system of the missile have an servo-control electro-mechanic which takes commands from the guidance system and control the control surfaces of the missile, consisting of directional fins, to position the missile to the target or facilitate tracking maneuvers (Fleeman & Schetz, 2012).

The main research studies regarding to ballistic missiles can be divided in some domains: design and construction of the missiles (Luo, Yang, & Chen, 2006), aerodynamic flight performance calculations of the missiles (Zhang, Wang, & Liu, 2013), studies on detecting ballistic missiles (Liu, Mclernon, Ghogho, Hu, & Huang, 2012), research on control of the ballistic missiles (Wael & Quan, 2011), aspects of missile trajectory prediction (Harlin & Cicci, 2007).

2. Design and Manufacturing Technologies of Missile Ballistic Components

For the design of the missile was used the design and modelling program CATIA V5 R21, in which was made an design of the component piece of the missile model, based on the existent missile model. This air to air missile model presents a modified internal structure and more resistant. In Table no. 1 are describes the main dimensional features and flight performance of the ballistic missile designed.

Table no. 1
General features of the missile designed

Length	3,100 mm
diameter	160 mm
Weight of the missile without fuel and explosive charge	73.5 kg
Weight of the missile with fuel and explosive charge	99.5 kg
Fuel tank	15 L
Warhead	Mixed warhead 11 kg
Guidance	Electro-optical guidance system + infrared guidance system + LOBL (lock-on before launch) system + LOAL (lock-on after launch) system
Range	> 20 km (up to 80 km)
Used materials	Duralumin – 30 % ; Stainless steel – 8 % ; Titanium – 62 %
Maximum speed	Up to Mach 7

This used structure is an idea which was applied for eliminate the force which appear on the missile skin. The model is designed for a better maneuverability to a range of speeds up to Mach 7. The concept is modular, the 3 modules are, start from the back to the top: engine module; explosive module (mixed warhead); guidance and control system module. During the evolution, the missile can execute a 180° return, tracking the target which predefined by the pilot, before the lunch. To execute this maneuver, the missile have 10 directional fins, 8 fins to execute tight turns and 2 fins for executing maneuvers to change the angle of incidence. Considering the range of speeds in which the missile evolves (the speed of the plane which the missile was launched on is consider equal with 0 m/s, start point), 62 % of the missile parts are made of titan, these parts which are exposed on high temperatures, because the melting point of the titanium is achieved at a temperature above 1649 °C.

2.1. Engine Module

The designed was realised on each module. The first module is the engine (Figure no. 2). This module is the biggest one, it is the most expensive because it incorporates the most elements made of titanium.

Figure no. 2. Engine module of the missile

The geometrical and functional feature of the engine module has been described in Table no. 2.

Table no. 2
Geometrical and functional features of the engine module

Length	1900 mm
Diameter	160 mm
Diameter with stabilizing fins	482 mm
Used materials	Duralumin – 20 %; Stainless steel – 12 %; Titanium – 68 %
Used engine	It was undersized an intercontinental missile engine with liquid fuel
Fuel ratio for an ideal combustion	For an ideal combustion, the proportion of fuel must be the next one: 1 ml fuel – 14.8 ml comburent
Fuel, Comburent	Kerosene , Peroxide

Thanks to use of such type of engine, even if this engine was undersized, the missile can evolve in completely different range of speeds, which means that the speeds increase thanks to engine power. This constructive solution was special chosen to achieve the maximum speed of Mach 7 that makes this air tot air missile to be peerless from the point of view of speed.

In Table no. 3 were presented the characteristics of the missile tank.

Table no. 3
Missile tank

Capacity	15 L
Length	900 mm
Diameter	140 mm
Internal configuration	Bicameral
Material	Dural
Filling method	Have filling valve

In Figure no. 3 are presented the engine tank of the ballistic missile, the supporting bars and specific undertakings.

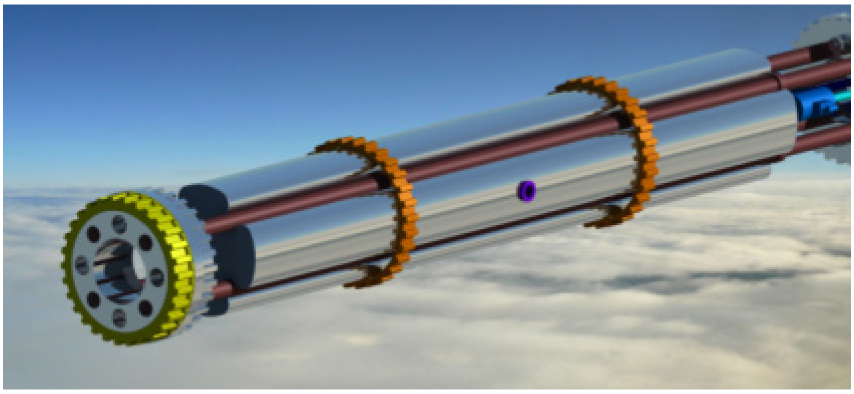

Figure no. 3. Engine tank with supporting bars and specific undertakings

After tank there are willing the flow control pumps which takeover the fuel through pipelines, transporting and adjusting the flow and pressure of fuel toward combustion chamber (Figure no. 4), where combustion occurs and obtaining the jet reaction depending of the acceleration of the missile. The combustion for obtaining the jet reaction is realised in combustion chamber. This jet reaction is directed to nozzle through multiple subassemblies. These subassemblies are:

– The flow reaction control nozzle: it aims to shrink the flow of gas mixture obtained in the combustion chamber and increase pressure of gas mixture;

– The flow control discs support: it sustains the flow control discs of gas mixture;

– The flow control discs: there are 5 and there have the role to create a high pressure of the jet reaction for a strong flow realise, such that the acceleration be very fast;

– The nozzle reaction: it is a tube with various sections, it was in the final part of combustion chamber of the reaction engine and it has the role to increase the kinetic energy of the combustion gas, released as a jet.

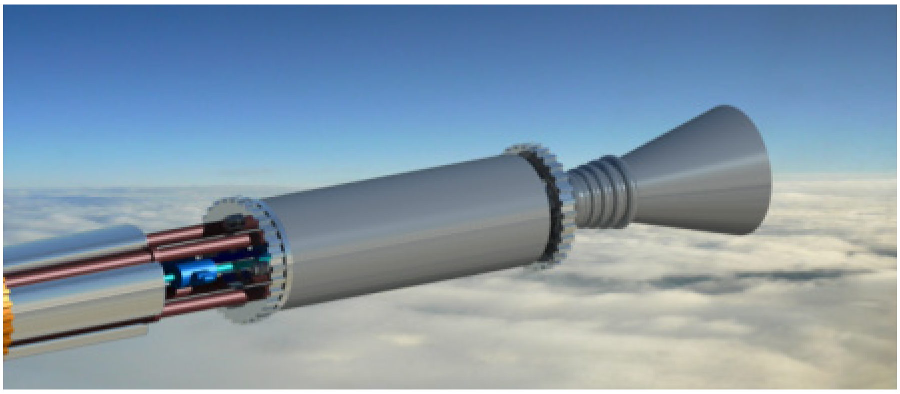

Figure no. 4. The combustion chamber with control parts of gas mixture

After designed the internal configuration of the engine, together with clamping structures of type clamping nuts (clamping structures for supporting the tank and clamping structures for supporting the combustion chamber), it was applied the skin of the missile, made from two types of sheet metal, profiled one that adds strength to the structure of the missile and external one which create an laminar flow of the air fillets on the external profile of the missile. These clamping structures together with the two skins represents the structure of resistance of the missile, an structure which was adopted to eliminate the torsion momentum and banding momentum of the internal parts of the missile, an innovative structure which hasn't applied to another missiles. This structure of resistance is found also at the other two modules, in small dimensions regarding the sheet metals which used on the skin, and in smaller number regarding the clamping structures. For making the connection between the modulus it used a part named connection flange modules. Without this part, the modulating of the missile it would have been impossible, considering the idea to eliminate all the external clamping that disturb the laminar flow regime by the appearance area swirl. The connection flange modules – makes the connection between the modules, making a subassembly, with clamping nuts module, because of the external thread. Geometrical configuration of the connection flange: it has an outer diameter of 162 mm with a thickness of 65 mm and an inner diameter of 70 mm it has two external threads M132x2 for achieving the assembly with clamping nut module.

2.2. Explosive Module

The next module it consist by the explosive module (Figure no. 5), the module without which the missile would not have military purposes. This module is the cheaper economically speaking and the most easily achieved in terms of production and mounting. The mixed warhead is the explosive element; being detonated on the impact with an auxiliary warhead which is in the top of the main warhead. Thus explosive module contain two warheads, one is the detonator with smaller quantity of explosives (1 kg) and one that is detonated with a capacity of 10 kg of explosives, which destroying the target aircraft.

Table no. 4

Geometrical and functional features of the explosive module

Length	785 mm
Diameter	160 mm
Warhead type	Mixed warhead
Materials	Duralumin – 45 % ; Titanium – 55 % ;

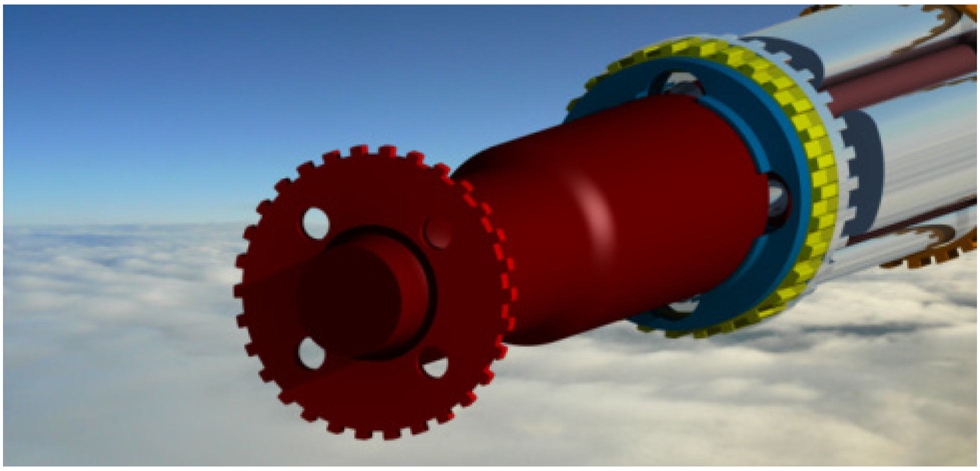

Figure no. 5. Explosive module with components

2.3. Guidance System Module

The last module, but the most important is the guidance and control system module (Figure no. 6), module without which the missile would not class in range of the guidance missile. In this module are incorporating the guidance system and control system of the missile: electro-optical guidance system; radar guidance system; infrared guidance system; LOBL guidance system (lock-on before launch); LOAL guidance system (lock-on after launch).

Figure no. 6. Guidance and control system module

Control of all components is achieved in this way, the missile has a central computer that stores data from guidance systems, being able to think independently. Using electro-optical system, missile stores the topography and targets which is in the visual range of the aircraft that was achieved with the help of LOBL guidance system. Featuring next-generation systems, the missiles is interconnected with the pilot thanks to LOAL guidance system and have a additional guidance with the help of the smart helmet which the pilot who launched the missile it has.

These guidance systems are made for air supremacy of the missile. The electro-optical system identify all targets are in sight since the peer lease stage. The launch gives a huge boost to the missile, which fall the missile on the straight line, but, because of the guidance systems and the central computer, the missile is capable to follow the target during the execution evasion maneuvers. Existing countermeasures on the fighters cannot eliminate the missile during air fighting because, if a guidance system was jammed, comes another of the other five. Thus the percentage of the success in air fighting of this missile is 90 %.

The main jamming ways: the electro-optical system can be jammed during air fighting by clouds or by elements reflecting sunlight; infrared guidance system can be jammed by the flares; the active radar system can be jammed using anti-radar systems mounted on the fighters. Although there are jamming systems of the guidance systems, the guidance systems of this missile are interconnected, so if one of 3 listed above is jammed, remains the guidance and control LOAL system with which the missile can be guided to the target. These communication systems have directly connection with the pilot via the smart helmet which enables accurate targeting to the missile for target aircraft.

The external configuration of the ballistic missile (Figure no. 7) have 10 control surface, 8 directional surfaces for cornering execution and 2 for maneuvers of execution to change the angle of incidence, and 4 stabilizers direction. During the evolution, thanks to the guidance and control systems, but mostly because of the control surfaces, the missile can execute a turn back to position on the quick and easy path to bring down the target aircraft.

Figure no. 7. External configuration with command surfaces

Chosen materials for construction of the missile determined a total mass of 99.5 kg, which ranks this designerd missile to be the easiest in its class of smart trajectory missile. Modulation adds additional reliability and efficiency when changing engine modules, explosive modules or guidance and control modules, for use as much this missile, according to the needs appears in air fighting.

Using titanium in percentage of the 68 % makes this missile to be most expensive, but also, together with undersized intercontinental missile engine gives it the capacity to evolve on the high speeds regime, superior to other air to air ballistic missile, Mach 7 (8,500 km/h), on the straight trajectory. For a better highlight of this thing, the missile like this model evolves at a speed up to Mach 4.

3. Conclusions

Internal structure is a new structure which gives a better resistance to the missile to banding and torsion force. The smooth external surface adds a better aerodynamics to the missile and allows better handling that is achieved by the two types of control surface. The guidance system is an existent system applied on another types of missiles with 100% functionality and accuracy hitting is 5 m at a distance of 80 km from the launch point. For missile guidance is realised a pilot-radar-missile triangulation of communication. This missile is a multirole missile which can be adapted: ground to air, air to ground or air to air. Thanks to intelligent guidance systems, the missile can't be shut down by conventional defense systems or countermeasures.

The technology of manufacturing the skin and the clamping parts is an easy one, which leads to a low manufacturing cost from the point of view of processing operations, but not in terms of the top materials used in the construction of the parts.

Bonding technology of the skin is a new technology applied to military aircraft structures, which was not applied on the taking of the missile skin, the skin being attached with rivets. This technology brings an ease of mounting and more efficiency on the mass of missile by removing the rivets. The double skin has a dual role; it is a resistance skin (the skin made of profiled sheet metal serving as a longitudinal resistance element) and the outer smooth skin, to achieve laminar flow.

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