THERMOTECHNICAL PROCESSES APPLIED TO AVIATION MISSILES

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Abstract: *Study and exemplification of thermodynamic processes with applications in aeronautical rocket technology important for propulsion, with monitoring of the fuel combustion phenomenon, respectively presenting the achievement of higher speeds using the divergent convergent nozzle.*

Keywords:*, thermal control, solid-fuel engines, convergent divergent nozzle.*

1. INTRODUCTION

The article attempts to present aspects of thermodynamic applications in aviation missile propulsion with the advantages and disadvantages depending on the type of liquid or solid fuel.

Allow me to make some classifications of combat missiles specific to military aviation according to: the type of target targeted, the type of fuel used by the rocket engine and the type of missile guidance to the target.

According to the type of objective or the method of hitting the intended target, we have the following types of aviation missiles, see table no.1.

Table no.1

Classification criterion	**Types**
According to the type of target or target targeted:	- air-to-air missiles; - air-to-surface missiles.
According to the type of engine fuel:	- with solid fuels; - with gas fuel; - with hybrid fuel; - with liquid fuels.
According to the method of ensuring guidance to the target or objective:	- unguided; - guided (active, semi-active, passive)

In today's air combat, effectiveness and survivability no longer depend solely on the agility of the aircraft, but on the kinetic energy transposed into the superior speed of combat missiles.

The rocket engine in these weapons has grown technologically from a simple impulse generator to a system of chemical mixtures and ultra-adapted aerodynamic profiles.

Before presenting aspects related to the propulsion of aviation missiles, we make a brief, general presentation of the structural composition, presented in FIG. 1 below. [1]

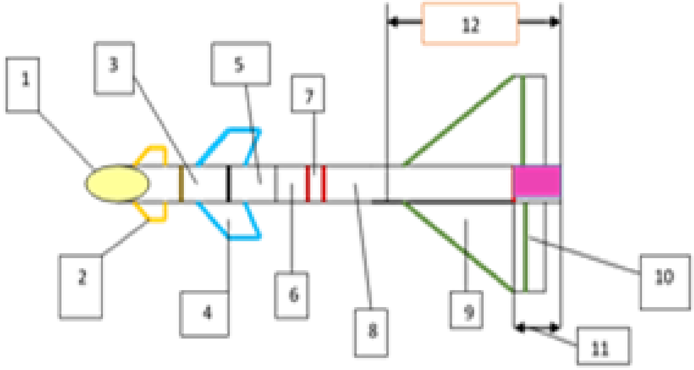

FIG.1 The main components of an aviation rocket :
1– steering sensor; 2 – destabilizers; 3 – rudder controls; 4 – rudders; 5 – autopilot; 6 – power supply compartment; 7 – warhead; 8 – combat component; 9 – steering wings; 10 – ailerons; 11 – engine nozzle (aileron controls and gas-dynamic rudders). 12. Rocket engine. [1]

In general, their role can be described as follows [1]:

- ✓ The guidance head – captures the signal from the target, transforming it into an electrical signal, which it sends to the autopilot that operates the missile controls.
- ✓ The autopilot compartment – based on the information received from the target, analyzes and transmits the appropriate signals to the command compartments.
- ✓ The command compartments – based on the signals received, develop the energy necessary for aerodynamic modification in order to track the target.
- ✓ The combat component – provides the useful effect when the missile approaches the target. The moment of action is determined by the warhead.
- ✓ The energy compartment – provides the electrical energy for the other compartments (controls, guidance head, etc.).
- ✓ The rocket engine – generates the traction force necessary to increase the speed of the missile from leaving the launcher, creating a reserve of kinetic energy sufficient to reach the target.
- ✓ The aerodynamic surfaces of these missiles are the lifting wings, aerodynamic controls,
- ✓ Aerodynamic destabilizers, if any, are located in the front of the missile, their role being to increase the missile's maneuverability, generally being fixed surfaces relative to the missile's body.

The solid fuel engine provides fast dynamics, rapidly increasing the rocket's acceleration, achieving top speeds of over Mach 4 in up to 5 seconds.

2. APPLICATIONS AND INTERPRETATIONS OF THERMOTECHNICAL ASPECTS SPECIFIC TO AVIATION MISSILES

Liquid fuel rocket engines : the fuel and oxidizer used to obtain the working agent are in separate tanks, being mixed in a combustion chamber where combustion takes place. from here the mixture of combustion gases enters the nozzle where expansion takes place. the advantages are that, unlike solid combustion engines, the fuel and oxidizer flows can be adjusted and controlled. this way, the thrust can be modified, and the engine operation can be stopped at certain times. The disadvantages are mainly related to the complex construction and the stability over time of the fuel and oxidizer.

Hybrid fuel rocket engines - hybrid chemistry (e.g. paraffin with liquid oxygen) offers a higher boost than solid fuels.

He gaseous fuel for rockets (gaseous oxygen, hydrogen, methane, etc.) is kept in compartments at very high pressures. the gases mix and burn instantly in the combustion chamber, producing thermal energy that will be transformed into kinetic energy that will propel the rocket. we can mention the constructive simplicity of the engine, high reliability and the possibility of easy control over the engine's operating modes. the disadvantages arise from the large volume of the gas storage compartments, low autonomy with low mass transport.

Solid fuel rocket engines : the working agent comes from the combustion of a fuel with a very high chemical potential. This fuel contains both the fuel and the oxidizer (the element that maintains combustion) in an initial mixture in solid form. It is distinguished by its great simplicity and has no moving parts.

The most commonly used nozzle in solid-fuel engines is the convergent-divergent nozzle, also called the Laval nozzle, which has three parts:

- ✓ a convergent zone, which directs the flow of gases under high pressure and which have low velocity at the inlet, a zone with the smallest surface area where the gases have high temperature, high pressure and low velocity, subsonic (M<1);
- ✓ the critical zone, where the exhaust gases are compressed with increasing supersonic velocity (M=1);
- ✓ a divergent zone – the nozzle exit – which increases the exhaust gas exhaust velocity **V** with decreasing temperature **T** and pressure **p** , exponentially increasing the propulsive force (M>1).

Those presented can be easily identified in FIG. 2 below:

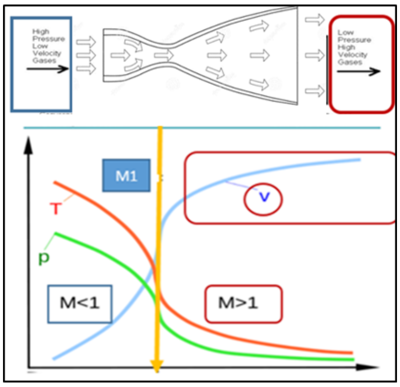

FIG.2 Diagram of a de Laval nozzle
(https://www.jacobsrocketry.com/rocketry_overview.htm,
https://physics.stackexchange.com/questions/283628/de-laval-nozzle-geometry)

The expansion of gas in the nozzle is a thermodynamic phenomenon in which the thermodynamic potential obtained from the chemical reaction is transformed into kinetic energy, correlated with the propulsion of the exhaust gases.

Solid-fuel reactive engines based on chemical energy are jet thrusters.

The linear velocity of the exiting exhaust gases can be calculated using the following equation 1:

$$v_e = \sqrt{\frac{TR}{M} \cdot \frac{2\gamma}{\gamma - 1} \cdot \left[1 - \left(\frac{p_e}{p}\right)^{\frac{\gamma-1}{\gamma}}\right]} \qquad (1)$$

Where**:**

V_e = exhaust speed ,

T = initial absolute temperature of the gas,

p_e = absolute gas pressure at the outlet,

M = the gas molecular ,

$\gamma = c_p/c_v$ = isentropic expansion factor,

cp , cv = specific heats at constant pressure and volume of the gas,

R = universal gas law constant,

p = absolute pressure of inlet gas [2][3][4].

The fuel reacts with the oxidizer in a strong exothermic reaction and we observe that the square of the exhaust velocity is directly proportional to the temperature of the exhaust gases, which gives the final reaction.

An innovation is found in the Meteor rocket where, upon launch, the solid-fuel rocket engine accelerates the rocket in the first seconds to a supersonic speed (classic launch).

Then a new Ramjet phase enters: the rocket has side intake ports that allow air (oxygen) from the atmosphere to enter the engine at speed and meet the gases rich in solid fuel, generating intensive combustion velocity of the rocket. [5]

We can see that with the decrease in the mass of the fuel we also have an increase in the speed of the rocket.

Unlike ramjet missiles, AMRAAM 120 C missiles contain the oxidizer in the solid fuel block inside the missile and operate in two stages:

- *stage 1*, intense acceleration, following a strong combustion reaction, obtained by the oxidizer mixture inside the missile resulting in an immense thrust with the rocket propulsion in a few seconds at speeds over Mach 4.

- *stage 2* is maintenance: continuous combustion through a small section tubing, with a low consumption rate. This stage maintains the kinetic energy that is translated into high speed of the missile on the last part of the trajectory. [6]

CONCLUSIONS

Chemical (solid) rocket engines are mainly used for the propulsion of aviation missiles, with the following specifications:

- chemical reaction carried out in the combustion tube produces a gas mass at high pressure and high temperature that develops thermal energy transformed into a propellant applied to the inlet of a convergent-divergent nozzle;
- the gas mass resulting from the chemical reaction when passing through the nozzle, at the exit, increases its volume with the loss of pressure and temperature but at supersonic speed;
- the strong increase in the exhaust speed of the gases at the exit of the nozzle, develops a higher acceleration that, relative to the mass of the exhaust gases, imparts a thrust force to the rocket that propels it at supersonic speeds;
- the amount of thermal energy that is transformed into kinetic energy, following the chemical reaction, is limited both by the mass of the reactants, and by the type of their chemical bonds in the reaction and the result of the reaction; this makes chemical (solid) fueled rockets limited in range.

We can say that this kinetic energy obtained by the engine and transposed into a significant speed of the aviation missile must be synchronized with advanced sensors for acquiring data for tracking the intended target and the guidance and maneuver elements necessary to bring the combat component into the impact zone calculated by the warhead to reach the objective.

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