CONSIDERATIONS REGARDING THE PERFORMANCE OF COMBUSTION CHAMBERS FOR TURBO-JET ENGINES

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Abstract: *The proposed systems are capable of generating o form of energy transferred to a fluid and transformed into work process. The turbojet combustion chambers uses air as work fluid, it forms a chemical mixture transforming energy fuel (petrol and air) into thermal energy through a process of isobaric fire. The article aims to highlight the role and the design of the combustion chambers for jet engines construction.*

Keywords*: turbojet engine, combustion chamber, GasTurb, numerical simulation*

1.INTRODUCTION

1.1. Overviews

The proposed systems are capable of generating o form of energy transferred to a fluid and transformed into work process. These systems consist mainly of fluid propulsion (air or gas combination) and an energy source capable of generating the energy required for fluid acceleration.

The jet engine is a part of the mechanical propulsion systems with air-jets which have air as working fluid, the energy source is represented by turbocharger group compressor and the propulsion system is represented by a reaction nozzle.

In figure 1.1 we can observe the jet engine on a multirole aircraft General Dynamics F16 Fighting Falcon, a version being present and used by Romanian Air Force.

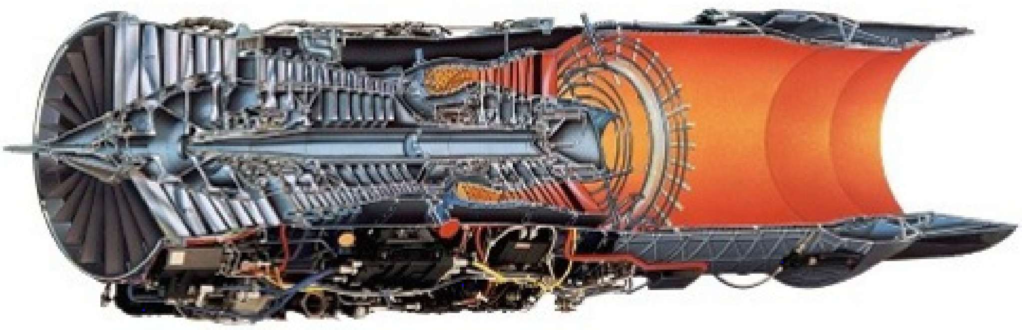
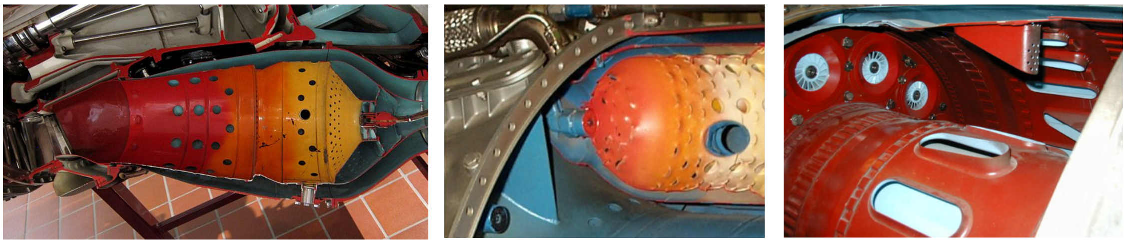


FIG. 1.1 Pratt-Whitney F100-PW220, [4].

1.2. The classification of turbo engines from the combustion chambers point of view

There are three types of constructive combustion chambers known from the following points: functional and constructive. These are individual, ring and mixed, see figure 1.2, [2, 3].

Another classification criterion is the flow direction of the working fluid in the combustion chamber: parallel flow chambers (flow purpose has the same direction as the system), countercurrent chambers, radial combustion chambers (the fluid flowing direction is radius with the directorate of the combustion chamber).



(a) (b) (c)

FIG. 1.2 Chamber combustiont ypes , a.individual, b.mixt c. ring,

2. COMBUSTION CHAMBER

2.1. Constructive principles

The combustion chamber uses air as a working fluid at a speed of Mach 0.2-0.3. She transforms the chemical energy of the fuel mixture (air and oil) into thermal energy by means of some isobaric combustion process. The combustion chamber has two streams: central flow (primary) and secondary flow. The primary air stream is combined with the fuel (the temperature is less than 225^0C) in the combustion chamber ensuring a stoichiometric combustion process, the combustion takes place at a temperature range of $2000^0 \div 2300^0$ K. In the process of combustion (exothermal) resulting combustion products which have to be cooled to enter the turbine, the cooling is conducted by means of secondary flow which together with the products of combustion form combustion gases, see Figure 2.1, [1, 7, 8, 9, 10, 13] .

Under theoretical combustion conditions we considered the maximum speed is fresh, mixtures that work using a combustion chamber with minimum overall dimensions and minimum weight.

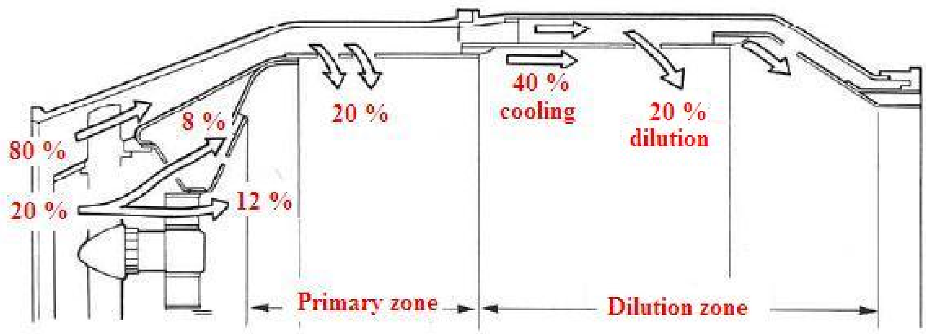


FIG. 2.1 Air flow in combustor

The temperature T_3 of the combustion gases out of the combustion chamber and the turbine depends on the composition of the combustion gases, if the temperature is low when the excess air from the secondary flow will be higher in the composition of the combustion gases.

In order to calculate the excess air we use the equation of energy conservation and the combustion mixture in the combustion chamber, namely: the sum of the total energies of the substances entering into the combustion chamber summed with the energy resulting from the combustion of air-fuel mixture and is equal to the total energy of the leaving substances from the combustion chamber, see equation 1, [6].

$$\dot{M}_a \cdot i_2^* + \dot{M}_c \cdot i_c + \xi_{ca} \cdot \dot{M}_c \cdot P_{ci} = \dot{M}_g \cdot i_3^* \quad (1)$$

Where $\dot{M}_a \cdot i_2^*$ energy due to airflow in the combustion chamber

i_2^* the energy of a kilogram of air,

i_C Enthalpy of one kilogram of fuel in gaseous state,

$\dot{M}_C \cdot i_c$ Energy due to fuel injection is,

$\dot{M}_c \cdot P_{ci}$ The heat released from burning,

P_{ci} The heat released by burning one kilogram of fuel and is equal to the lower calorific value of the fuel,

$\xi_{ca} \cdot \dot{M}_c \cdot P_{ci}$ It is taken from the exhaust gas energy (including losses due to heat transfer to the environment and incomplete combustion ξ_{ca})

$\dot{M}_g \cdot i_3^*$ Is the energy of one kilogram of gas out of the combustion chamber.

We also say:

$$\dot{M}_a \cdot i_2^* + \dot{M}_c \cdot i_c + \xi_{ca} \cdot \dot{M}_c \cdot P_{ci} = \dot{M}_g \cdot i_3^* \quad (2)$$

$$\dot{M}_a \cdot i_2^* + \dot{M}_c (i_c + \xi_{ca} \cdot P_{ci}) = \dot{M}_g \cdot i_3^* \quad (3)$$

where $i_c \approx 200\text{-}300$ kJ/kg, iar $P_{ci} \approx 43\,000$ kJ/kg, deci $i_c << \xi_{ca} \cdot P_{ci}$, deci:

$$\dot{M}_a \cdot i_2^* + \dot{M}_c \cdot \xi_{ca} \cdot P_{ci} \cong \dot{M}_g \cdot i_3^* \quad \text{şi} \quad \dot{M}_a \cdot i_2^* + \dot{M}_c \cdot \xi_{ca} \cdot P_{ci} \cong (\dot{M}_a + \dot{M}_c) \cdot i_3^*$$

$$i_2^* + \frac{\dot{M}_c}{\dot{M}_a} \cdot P_{ci} \cdot \xi_{ca} = (1 + \frac{\dot{M}_c}{\dot{M}_a}) \cdot i_3^* \quad (4)$$

and $$\frac{\dot{M}_c}{\dot{M}_a} = f(\alpha)$$

where α the excess of air.

In real combustion, excess air is between 0.4 ÷ 1.7, for rich blend value is 0.4, 1.7 for the lean, and the excess value for optimal air is 0.8. Limits are specific to each fuel, limits that lead to control and stabilize the flame in front of the tube fire, and when air excides a value of 1.7 the burning stops.

2.2. Requirements for combustion chambers

a. The combustion chamber must ensure a stable combustion process with a continuous flame and must be geometrical well-defined. The efficiency of the combustion process to be at maximal high (0.94 ÷ 0.98) with total and static pressure loss as small, see the equation 5.

$$\sigma_{ca}^{*} = \frac{p_3^{*}}{p_2^{*}} \tag{5}$$

Pressure losses in practice are between 0.95 ÷ 0.98 [10].

b. The combustion chamber must achieve uniform distribution of kinematic parameters and maximum temperature in the inlet section of the turbine (see Figure 2.2), by forming proper combustion chamber and the choice of an optimum number of tubes of fire, which is a compromise between pressure losses and distribution gear exiting the combustion chamber.

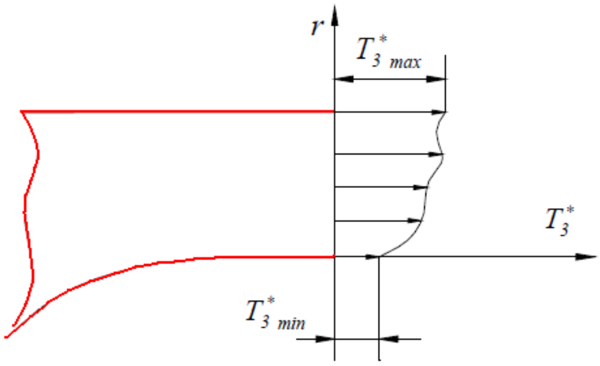


FIG. 2.2. The real distribution of the maximum temperature

Where can you define the degree of unevenness of distribution:

$$\delta_{ca} = \frac{T_{3\max}^{*} - T_{3\min}^{*}}{T_{3\max}^{*}} \tag{6}$$

For a well-designed combustion chamber value ratio is less than 0,2.

c. The combustion chamber must have a thermal load and a large operating resource.

d. The combustion chamber should be reduced to minimize the length sizing the compressor-turbine shaft and thus reduce weight and mechanical strength.

Combustion chambers as basic requirements are: simple manufacturing technology and the price of the lowest possible cost, cheap exploitation technology and satisfactory mechanical strength, [10, 11].

2.3. Fundamental performance

These are: the total pressure loss (and static), which is caused by three processes: friction, heating and mixing; the degree of heating of the fluid; combustion efficiency or burn perfection.

Total and static pressure loss is reduced with increasing air velocity through the chamber, but if airspeed out, C_2 of the compressor increases when its yield decreases, so the choice C_2 is a compromise between compressor efficiency and pressure drop in the combustion chamber . The same applies to compromise given the choice C_3 seeing a loss of the turbines efficiency in the combustion chamber.

The efficiency in the combustion chamber (ξ) is directly proportional to the heat loss and loss by mixing streams, see equation 7.

$$\xi_{ca} = \frac{Q_{ca}}{M_c \cdot P_{ci}} = 1 - \frac{Q_t + Q_{ai}}{M_i \cdot P_{ci}} \qquad (7)$$

Where Q_t *is the heat that is lost through transfer between the flue gas and the environment,*

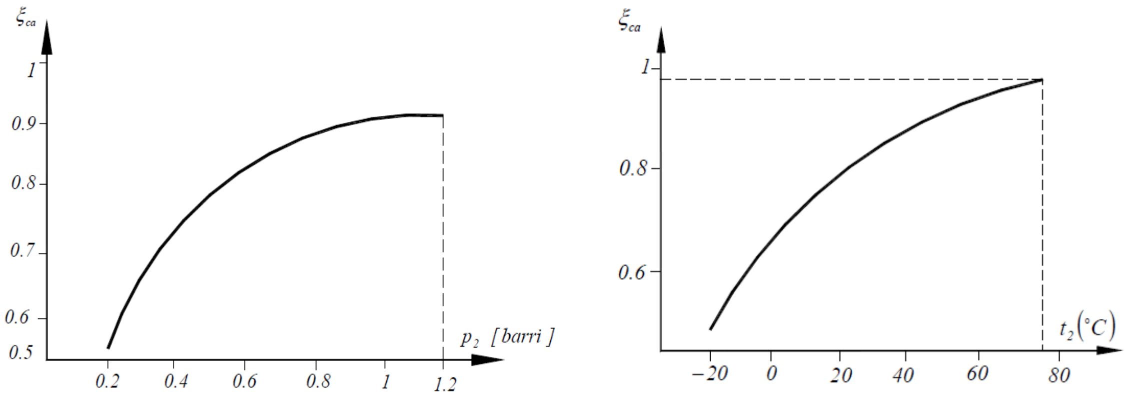
Q_{ai} *is the heat that is lost through incomplete combustion.*

Experimentally it is established that the efficient position for burning is below, equation 8 and Figure 2.3., it depend on pressure, temperature and air velocity exiting the compressor and excess air

$$\xi_{ca} = f(p_2, T_2, \alpha, C_2) \qquad (8)$$

.

From the charts in Figure 2.3a and 2.3b we can observed that the efficiency of the combustion chamber becomes quasi-constant after 1.2 Barrs and temperatures over 80^0C, and the influence on the yield excess air combustion chamber is given in Figure 2.4.



(a) (b)

FIG. 2.3. Dependence on burning efficiency T_2 and p_2

In figure 2.4 we can observe that at any flight height there is an excess amount of air (α_{opt}) that is the maximum combustion efficiency and while increasing flying height we decrease the amount of excess air and at the same time we lower the maximum combustion efficiency.

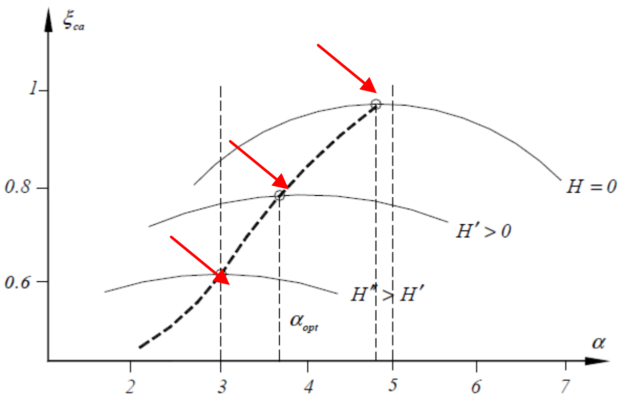


FIG. 2.4. Excess air influence on the efficiency of the combustion chamber.

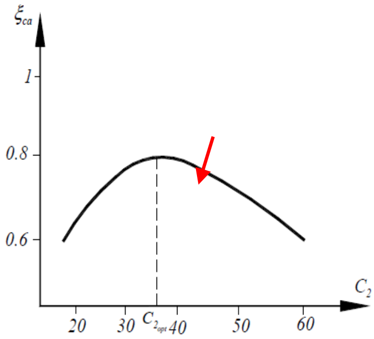


FIG. 2.5. Combustion efficiency according to C_2

Speed variation of the combustion efficiency of the compressor for the air leaving / entering the combustion chamber, shown in Figure 2.5. The physical explanation of the graphics is that at low speeds increase fluid component that is lost through heat transfer and thermal component increases at high speeds due to incomplete combustion, so there is an optimal speed C_{2opt} which is maximum combustion efficiency.

In Figure 2.6 we can observe the theoretical distribution on every subsets of the main parameters of a jet engine combustion chamber have constant pressure, an increase in temperature, flue gas velocity and hence the tractive force.

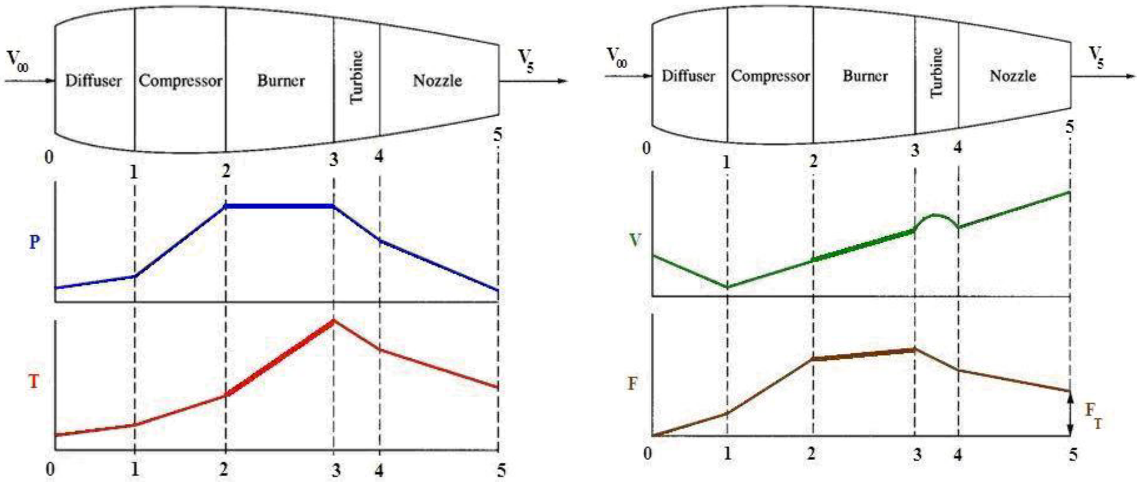


FIG. 2.6 The variation of main parameters of jet engine

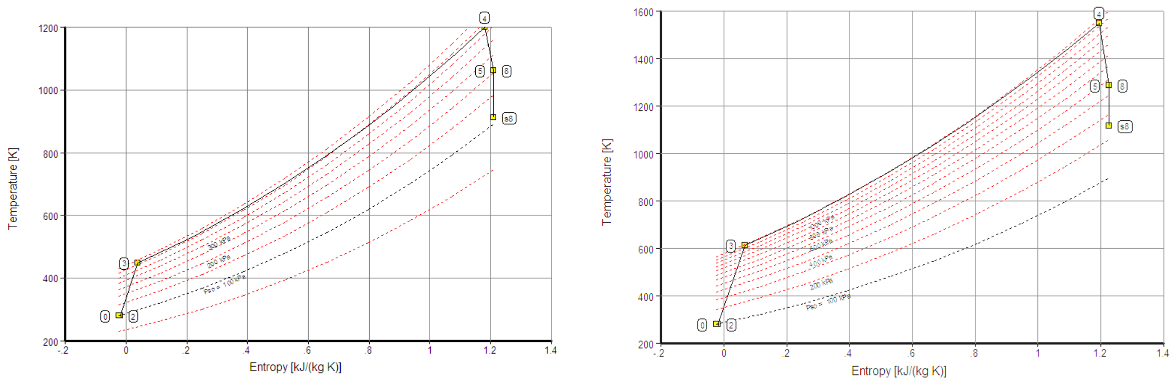
3. NUMERICAL SIMULATIONS

3.1. Single cycle

To highlight the influence of operating parameters on the performance of the combustion chamber for a jet engine flight we used a software tool, GasTurb 9 and the parameters from Table 3.1 in two modes of operation, [5].

Table 3.1. Operating parameters of the combustion chamber

Mode A		Mode B	
T_1 / P_1		280 K / 99 kPa	
ξ_C / ξ_T		0,85 / 0,89	
Fuel		generic	
Traction coefficient nozzle / nozzle angle slats		1 / 20^0	
T_{A4}	1200 K	T_{B4}	1230 K
P_{A4}	0,9	P_{B4}	0.9



(a) (b)

FIG. 3.1. Depending on the temperature variation of entropy, mode A (a), mode B (b)

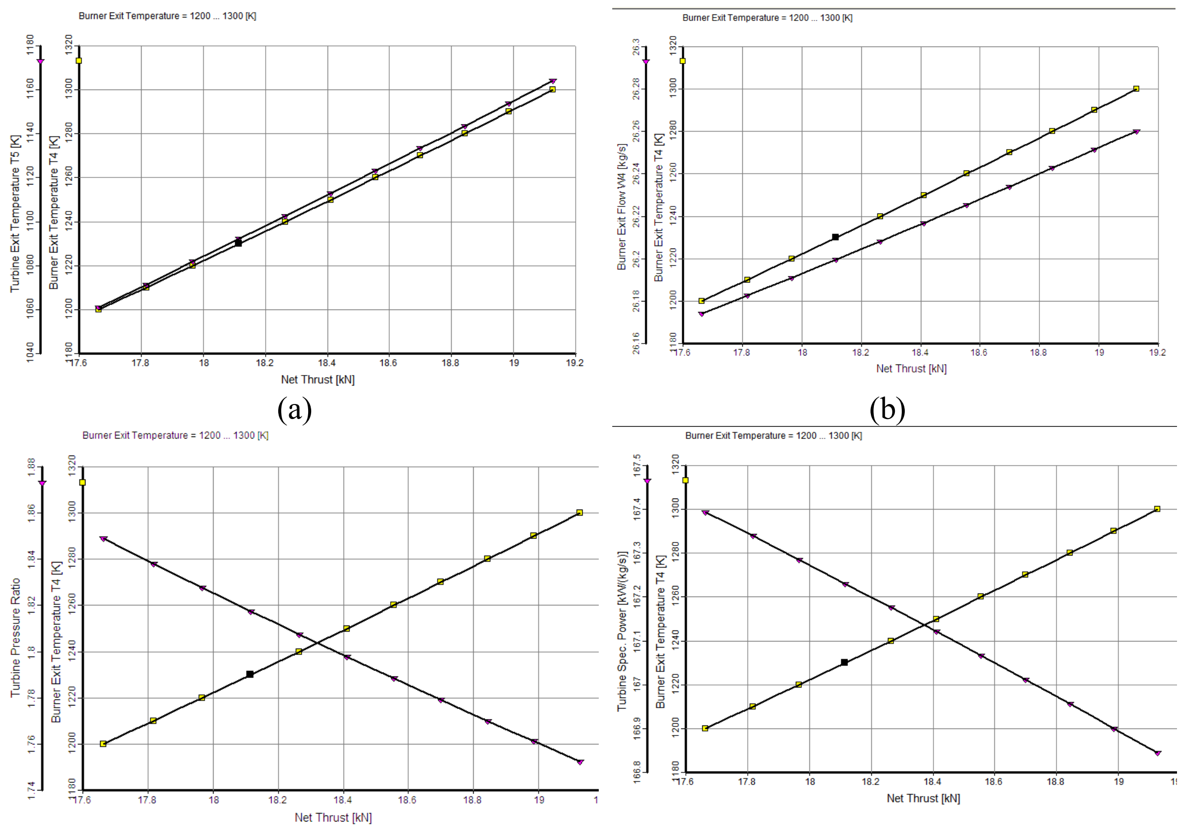
In figure 3.1 we observed differences in variation of entropy (in both cases) depending on temperatures (1350 K to 1550 K) which runs the burning fuel mixture (with preheating the fuel to 40^0C) for a burning temperature of 1200 K engine develops a trust of 17.66 kN to 1230 K and we value 18.12 kN thrust calculated values close to those conveyed in references specialty [12].

3.2. Parametric case

For parametric study we used the initial data in Table 3.2 following the evolution of the main features of jet engine analyzed.

Table 3.2. Combustion parameters

Temp. T_1	280K	Inlet flow	26,1 kg/s
Pres. P_1	99kPa	Temp. T_4	1200 ÷ 1300K
Relative humidity	0%	Burner pressure ratio	0.8 ÷ 1



(a) (b) (c) (d)

FIG. 3.2. Turbojet engine characteristics

In Figure 3.2.a is observed for the linear dependence of the net traction depending on the exhaust gas temperature T_4 at the exit of the combustion chamber and the temperature T_5 at the outlet of the turbine. Linear traction motor function and increase the amount of flue gas (see Figure 3.2.b).

For optimal values of T_4 and turbine parameters (P_5 and specific power) results in an optimal range of between 18.2 ÷ 18.4 kN thrust (see Figure 3.2.c and d).

4.CONCLUSIONS

The efficiency of the combustion chamber increases with increasing altitude and due to the specific characteristics of the fuel, such as vaporization latent heat, the viscosity, the temperature of solidification (freezing), the content of the gums or the temperature of flammability and explosion hazard.

The combustion process in the combustion chamber to the jet-engine, according to the specialized references [9, 13], can be streamlined and geometric optimization methods and experimental CFD

Using software tools for the study of variation parameters for turbojet engines we can highlight the operating limits for components considered singular or interdependent.

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