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TURBO-DOUBLE FAN ENGINE

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Abstract: *The paper analyzes the thermodynamic scheme of a derived engine from the reference tubofan CFM56-7B27 (Snecma&General Electric), used by Boeing 737-300, C-40 Clipper, P-8 Poseidon, Project Wedgetail. This engine thermodynamic scheme has two fans which split the fan based air flow in two propulsive air jets. The intention of this work is to find how they are changing some takeoff conditions (sea level) such as the thrust, the fuel consumption, the propulsion jets velocities, and the evaluation of the jets noise by using the comparison of the radial relative flows velocities of the concentric jets for the turbo-double fan and the basic turbofan. The numerical results were obtained following two ways of cycle modification: 1st way maintained the by pass ratio and the maximum compression ratio, and they were imposed the fan's compression ratios in the range 1.4 to 1.8; 2nd way maintained the maximum compression ratio and they were imposed the propulsion jets velocities to 465m/s, 308 m/s and (200 to 240) m/s. The numerical results showed that 1st way provides few advantages such as a slight increase of the thrust and a minor reduction of the specific fuel consumption [kg/daN/h], but the 2nd way might conduct to a major reduction of the specific fuel consumption [kg/daN/h], of about 30%, even the thrust decrease with about 20%.*

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Key words: *turbo-double fan, thrust at the sea level, fuel consumption.*

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1. Introduction and Assumptions

The scheme of the turbo-double fan was derived from the reference turbofan CFM56-7B27 (Snecma&General Electric).

http://www.cfm56.com/products/cfm56-7b

For this basic cycle, they were selected from the literature the following operational parameters (at the sea level):

- intake air mass flow rate: 359 kg/s
- by-pass ratio: 5,1
- total air compression ratio: 32,7
- thrust: 12143 daN
- fuel consumption: 1,284 kg/s
- specific fuel consumption: 0,38 kg/daN/h

For the derived variant of the turbo-double fan, they were adopted the assumptions:

- intake air mass flow rate: 359 kg/s
- by-pass ratio: 5,1 for 1st way, and computed for the 2nd one
  - total air compression ratio: 32,7
  - compressor isentropic efficiency: 0,88
  - fans isentropic efficiency: 0,92
  - intake pressure loss coefficient: 0,98

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- combustion efficiency: 0,97
- cooling air fraction: 0,03
- turbine isentropic efficiency: 0.94
- nozzle velocity loss coefficient: 0.99
- sea level air parameters: 1 bar, 288 K
- fuel higher heating value: 46000 kJ/kg
- fuel composition: 0,85 kg C/kg, 0,15 kg H2/kg
- intake air negligible humidity
- gases heat capacities interpolated by polynomials of 4th order.

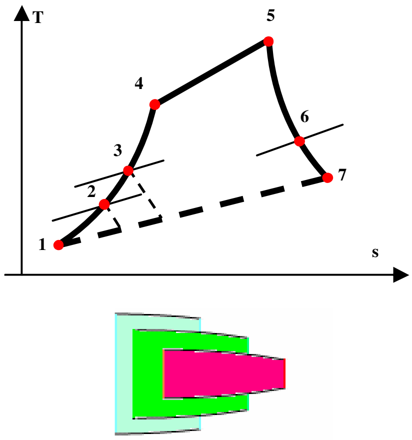

Fig. 1. *Diagram T – s of the TURBO-DOUBLE FAN*
1 – 2 *first fan's compression* (V1); 2 – 3 *second fan's compression* (V2); 3 – 4 *main compression process;* 4 – 5 *combustion;* 5 – 6 *flue gases expansion through turbine;* 6 – 7 *flue gases expanses through nozzle*

Additionly, they were adopted the variable domains:

- fans mass flows ratio:
  $K_V = G_{V1}/G_{V2} = 1, 2, 3, 4, 5$
- fans compression ratio:
  ε_{V1} (ε_{V2}) = 1.4 to 1.8, imposed autonomously for the 1st way,

and

$\varepsilon_{V1} * \varepsilon_{V2} = 1.7$ = const., for the 2nd way, but ε_{V1} and ε_{V2} computed by imposing the velocities of next jets velocities to (200, 221, 241) m/s for the first fan and 308 m/s for the second one.

2. Computational Procedure

The computational procedure followed the turbo-double fan cycle and considered:

- variable heat capacities, function of composition and temperature
- adiabatic exponents, computed by iterations, as the ratio of enthalpy variation to internal energy variation
- negligible dissociation during combustion
- mass and energy balance equations of combustion gave the flue gases composition, the excess air value, and the fuel flow rate
- global energy balance equation, equating the powers of fans, main compressor and turbine, provided the flue gases parameters before the nozzle.

3. Numerical Results

The selected numerical results are included in the Figures 2 – 8 regarding the first computational way, and the Table 1 for the second one, showing the relationships:

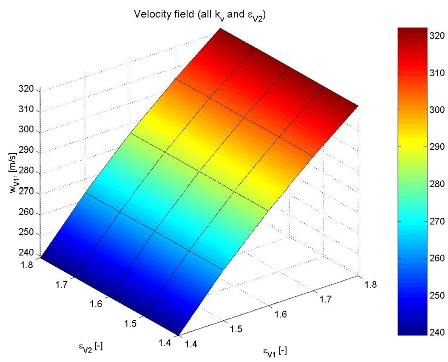

Fig. 2. *Propulsion jet air velocity from the first fan* (w_{V1}) *depending on the compression ratio of fans,* ε_{V1} *and* ε_{V2}*, for all* $K_V = G_{V1}/G_{V2}$

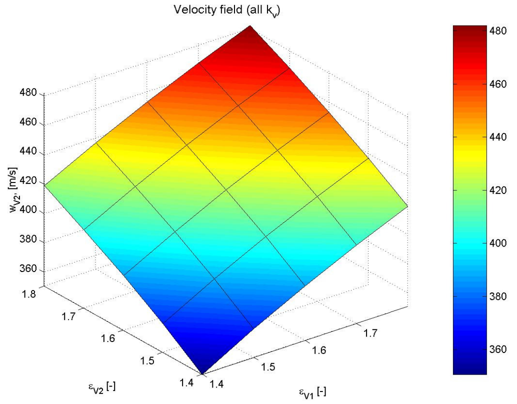

Fig. 3. *Propulsion jet air velocity from the second fan* (w_{V2}) *depending on the compression ratio of fans*, ε_{V1} *and* ε_{V2}, *for all* $K_V = G_{V1}/G_{V2}$

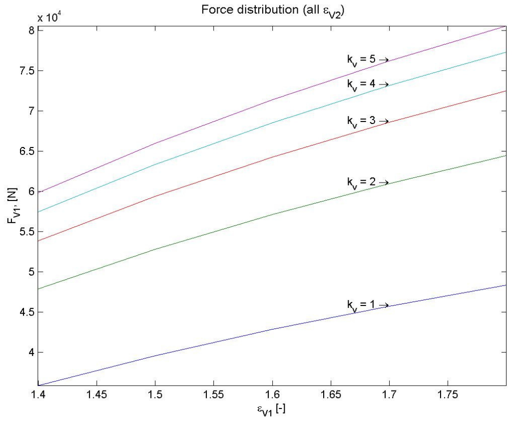

Fig. 5. *Thrust performed by the first fan* (F_{V1}) *depending on the compression ratio of fans*, ε_{V1} *and* ε_{V2}, *for all* $K_V = G_{V1}/G_{V2}$

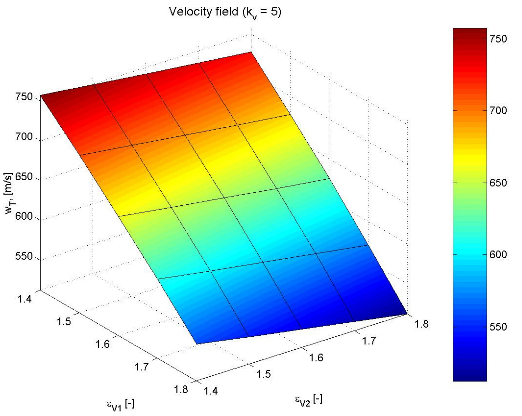

Fig. 4. *Propulsion jet flue gases velocity from the nozzle* (w_T) *depending on the compression ratio of fans*, ε_{V1} *and* ε_{V2}, *for* $K_V = G_{V1}/G_{V2} = 5$

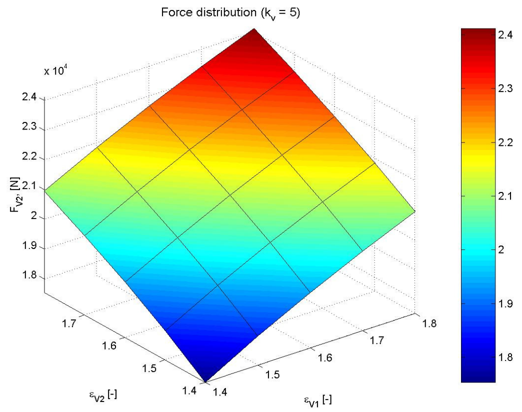

Fig. 6. *Thrust performed by the second fan* (F_{V2}) *depending on the compression ratio of fans*, ε_{V1} *and* ε_{V2}, *for* $K_V = G_{V1}/G_{V2} = 5$

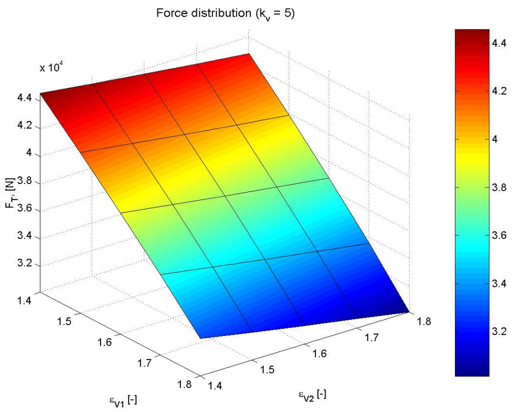

Fig. 7. *Thrust performed by nozzle* (F_T) *depending on the compression ratio of fans*, ε_{V1} *and* ε_{V2}, *for* $K_V = G_{V1}/G_{V2} = 5$

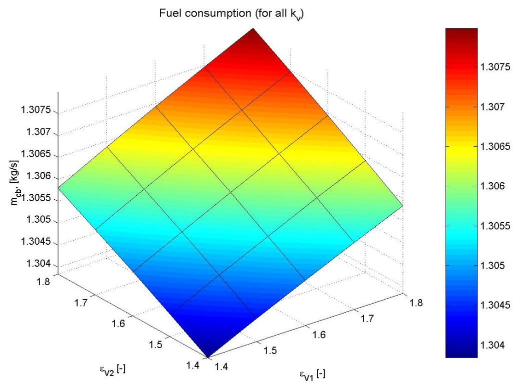

Fig. 8. *Fuel consumption* (m_{cb}) *depending on the compression ratio of fans*, ε_{V1} *and* ε_{V2}, *for all* $K_V = G_{V1}/G_{V2}$

Selected numerical results for the second computational procedure Table 1

	K := 12.53	K := 11.15	K := 10
	KV := 3	KV := 3	KV := 3
Air jet velocity, from 1st fan, [m/s]	200,58	221,73	241,74
Air jet velocity, from 2nd fan, [m/s]	308,28	308,29	308,28
Flue gases jet velocity, through nozzle, [m/s]	465,87	465,40	465,62
Thrust performed by 1st fan [N]	50013	54786	59171
Thrust performed by 2nd fan [N]	25623	25391	25153
Thrust performed by nozzle [N]	12636	14054	15531
Total thrust [N]	88272	94231	99855
Fuel consumption [kg/s]	0,5844	0,6506	0,7187
Specific fuel consumption [kg/dN/h]	0,2383	0,2486	0,2591
Compression ratio ε_{V1}	1,2650	1,3300	1,4000
Compression ratio ε_{V2}	1,3450	1,2793	1,2153
Mass flow rate of the jet from 1st fan [kg/s]	249,3461	247,0895	244,7727
Mass flow rate of the jet from 2nd fan [kg/s]	83.1154	82.3632	81.5909
Mass flow rate through turbine – nozzle [kg/s]	27,1229	30,1980	33,3550

4. Conclusions

Numerical results showed that the first computational way way provides few advantages such as a slight increase of the thrust and a minor reduction of the specific fuel consumption [kg/daN/h], but the second way might conduct to a major reduction of the specific fuel consumption [kg/daN/h], of about 30%, even the thrust decrease with about 20%.

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