CONTROL SYSTEM WITH AIR BLEED FLAPS FOR SUPERSONIC AIR INTAKES

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***Abstract*-The paper deals with an automatic control system for a class of supersonic intakes, based on the bleed air flaps' opening with respect to the aircraft's engine's operating regime. The control law $\delta = \delta(\pi_c^*)$ is established, which gives the univoc correspondence to the intake's rear pressure p_e. An automatic control system is studied, from the point of view of its mathematical model, its stability and quality. One has also performed some simulations in order to reveal the system's behaviour for several engine operating regimes, for a constant supersonic flight regime.**

Keywords: *air intake, inlet, flap, shock wave, control system, servo-amplifier, actuator.*

1. INTRODUCTION

The supersonic inlets and intakes for low supersonic speed aircraft (1.5 ‘ 1.7 Mach) or for high supersonic speed aircraft, mounted under the wing or on the fuselage, are less influenced by the flight regime's changes (altitude *H* and speed *V*) than the front intakes. This matter involves an intake design, manufacturing and control simplifying, that means that one can use a fix spike, fix panels and/or fix cowl, but one must assume some aerodynamic losses increasing, but small enough to induce intake's and/or the engine's malfunctions.

Although, the intake's control with respect to the engine's regime shall be realised by the air bleed flaps positioning, in order to match the delivered air flow rate to the engine's necessary air flow rate and avoid the intake's and compressor's stall. Such a control system is presented in fig. nr. 1, where the air intake (3), with or without spike (2), but with air bleed flaps (4), is laterally mounted on the aircraft fuselage (1) and delivers the necessary air flow for the engine (5).

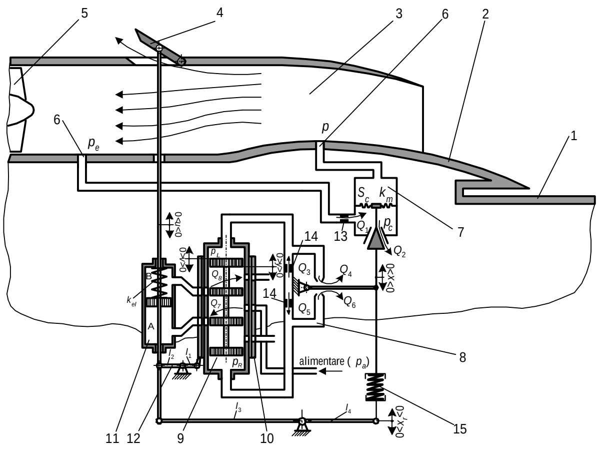

Figure 1: Automatic control system for supersonic intakes based on the air bleed flaps' opening

2. CONTROL LAW'S ESTABLISHING

The control law is the mathematical expression for the flap's opening with respect to one or more of the engine's and/or flight parameters. Air bleeding flaps' role is to control the internal shock wave positioning through the static pressure in section 1 control, that means the compressor's inlet's pressure $p_1(p_e)$, in order to assure the balance between the engine's necessary air flow rate and the intake's available air flow rate.

The shock wave must be stabilised in a precisely designed zone; the pressure $p_1(p_e)$ must have such a value, that in the minimum section area $1'$ the flow shall be sonic (critical) and a supersonic tampon-zone shall exist between $1'$ and the normal shock-wave (see figure nr. 2).

The shock-wave's position, as well the intake's total pressure ratio σ_{DA}^*, can be determined based on the flow's parameters, the pressure p_1 in the front of the compressor (the compressor's operating regime) and on the intake's geometry. One can assume a linear variation of the intake's flow section (from $A_{1'}$ to A_1):

$$A(x) = A_{1'} + \frac{(A_1 - A_{1'})}{L}x. \qquad (1)$$

A general form for the air flow rate's expression is [7]

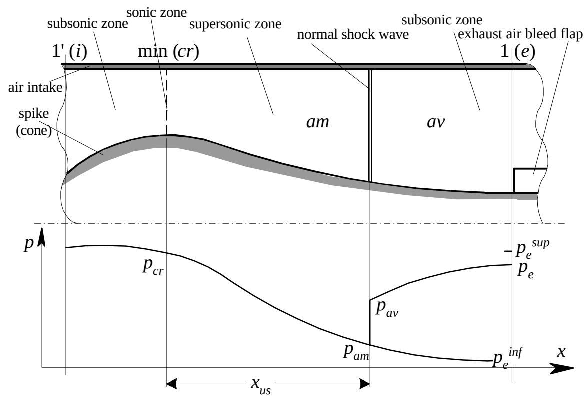

Figure 2: Internal shock wave's positionning

$$\dot{M} = KA\frac{p^*}{\sqrt{T^*}}q(\lambda), \quad (2)$$

where K is a constant which depends on the adiabatic exponent k and on the air perfect gas constant R $K = \sqrt{\frac{k}{R}\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$; one can express the flow rate for the sections $1', 1$ and for the shock-wave (before it "am", after it "av")

$$KA_{1'}\frac{p_H}{\sqrt{T_H^*}}q(\lambda_H) = KA_x\frac{p_{am}^*}{\sqrt{T_{am}^*}}q(\lambda_{am}) =$$

$$= KA_x\frac{p_{av}^*}{\sqrt{T_{av}^*}}q(\lambda_{av}) = KA_1\frac{p_1^*}{\sqrt{T_1^*}}q(\lambda_1), \quad (3)$$

where A_x is the intake's section area where the shock-wave appears.

One can assume [7] that $p_{av}^* = \sigma_{us}^* p_{am}^*, p_H^* = p_{am}^*$, $p_{av}^* = p_1^*, \lambda_{av} = \frac{1}{\lambda_{am}}$, $p_1^* = \frac{p_1}{\Pi(\lambda_1)}$ and knowing the flow's Mach number M_H one can determine λ_H, and from p_H and M_H it results p_H^*. From (3) one obtains

$$KA_{1'}\frac{p_H^*}{\sqrt{T_H^*}}q(\lambda_H) = KA_1\frac{p_1}{\Pi(\lambda_1)}\frac{1}{\sqrt{T_1^*}}q(\lambda_1), \quad (4)$$

$$\frac{q(\lambda_1)}{\Pi(\lambda_1)} = \frac{p_H^*}{p_1}q(\lambda_H)\frac{A_{1'}}{A_1}, \quad (5)$$

where λ_1 is unknown. This transient equation has two solutions for $\lambda_1, \lambda_{11} < 1$ and $\lambda_{12} > 1$; the right one is the first one, which gives sub-sonic flow regime in section 1. One obtains, from (3)

$$KA_{1'}\frac{p_H^*}{\sqrt{T_H^*}}q(\lambda_H) = KA_1\frac{p_1^*}{\sqrt{T_1^*}}q(\lambda_1), \quad (6)$$

with λ_1 above determined, $p_H^* = p_{am}^*, p_1^* = p_{av}^*$ and $\frac{p_1^*}{p_H^*} = \frac{p_{av}^*}{p_{am}^*} = \sigma_{us}^*$. The pressure loss ratio is given by

$$\sigma_{us}^* = \frac{A_{1'}}{A_1}\frac{q(\lambda_H)}{q(\lambda_1)}. \quad (7)$$

The same equation (3) leads to

$$KA_x\frac{p_{am}^*}{\sqrt{T_{am}^*}}q(\lambda_{am}) = KA_x\frac{p_{av}^*}{\sqrt{T_{av}^*}}q(\lambda_{av}), \quad (8)$$

which gives a transient equation with λ_{am} as argument

$$\sigma_{usd}^* = \frac{q(\lambda_{am})}{q\left(\frac{1}{\lambda_{am}}\right)}; \quad (9)$$

the correct solution is the super-sonic one, $\lambda_{am} > 1$, which gives, from the first equation (3)

$$KA_{1'}\frac{p_H^*}{\sqrt{T_H^*}}q(\lambda_H) = KA_x\frac{p_{am}^*}{\sqrt{T_{am}^*}}q(\lambda_{am}). \quad (10)$$

One obtains

$$A_x = A_{1'}\frac{q(\lambda_H)}{q(\lambda_{am})}, \quad (11)$$

and, from Eq.(1), one can determine the distance x_{us}

$$x_{us} = \frac{L}{\frac{A_1}{A_{1'}} - 1}\left[\frac{q(\lambda_H)}{q(\lambda_{am})} - 1\right]. \quad (12)$$

Using this algorithm one determines an univoc relation between the shock wave's position and the pressure in section 1 (given by the engine's operating regime-n and the flight regime-p_H, T_H, M_H).

In order to obtain an intake correct operation, the shock wave must be kept in a precisely determined zone and the excedentary air must be evacuated through the flaps' opening; the air flow rate balance equation, for a flight speed V and a flight altitude H is

$$\dot{M}_a = \dot{M}_{ac} + \dot{M}_{ap}, \quad (13)$$

$\dot{M}_a$=intake air flow rate, $\dot{M}_{ac}$=compressor's air flow rate, $\dot{M}_{ap}$=evacuated air flow rate; $\dot{M}_a = f(V, H, A_{1'})$, that means $\dot{M}_a = (M_H, A_{1'})$; $\dot{M}_{ac} = f(\frac{n}{\sqrt{T_1^*}}, \pi_c^*)$; $\dot{M}_{ap}$ depends on the pressure difference between the intake's inner zone and the atmosphere, as well on the flaps' horifice area (flaps' positioning)

$$\dot{M}_{ap}(\delta) = \dot{M}_a - \dot{M}_{ac}\left(\frac{n}{\sqrt{T_1^*}}, \pi_c^*\right); \quad (14)$$

$$\dot{M}_{ap} = \mu\sqrt{2\rho_1}\,A_V\sqrt{p_1 - p_H}, \quad (15)$$

where μ = shape flow rate co-efficient ($\mu \approx 0,7$), ρ_1 is the air density in section 1, given by

$$\rho_1 = \frac{p_1}{RT_1}, \quad (16)$$

A_V is the flaps' opening area

$$A_V = b_V l_V \sin\delta, \quad (17)$$

b_V, l_V=flaps' dimensions, δ=flaps' opening angle. So,

$$\dot{M}_{ap} = \mu\sqrt{\frac{p_1}{RT_1}}\sqrt{p_1 - p_H}\,b_V l_V \sin\delta, \quad (18)$$

$$\dot{M}_a = KA_{1'}\frac{p_H^*}{\sqrt{T_H^*}}q(\lambda_H). \quad (19)$$

A relation between δ-angle and the compressor's pressure ratio π_c or π_c^*, $\delta = f(\pi_c^*)$, respectively $\delta = \delta(p^*/p_1)$, which involves the $p_1 = p_e$ pressure in the front of the compressor is given in figure 3.

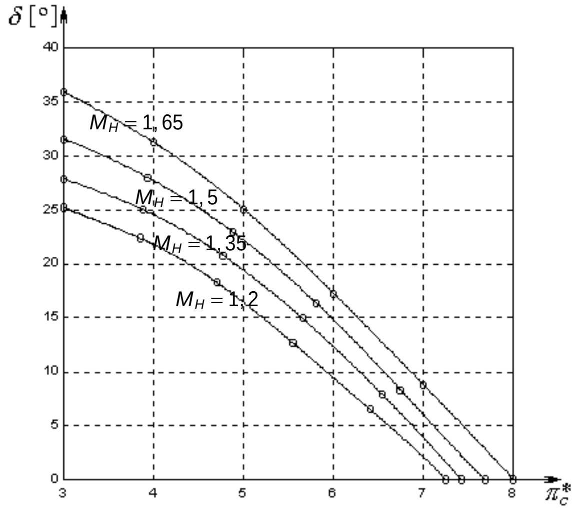

Figure 3: Control law (Flaps' opening angle with respect to the engine's compressor's pressure ratio)

3. SYSTEM'S MATHEMATICAL MODEL

3.1. System's non-linear equations

Non-linear equations establishing is based on the system functional diagram in figure 1 and consists of:

- transducer's (7) equations:

$$Q_1 = \mu_1 \sqrt{2\rho^{-1}}\ \sqrt{p_e - p_c}\ , \tag{20}$$

$$Q_2 = \mu_2 \sqrt{2\rho^{-1}}\, x \sqrt{p_c - p_H}\ , \tag{21}$$

$$Q_2 - Q_1 = \beta V_c \frac{\mathrm{d}p_c}{\mathrm{d}t} + S_c \frac{\mathrm{d}x}{\mathrm{d}t}, \tag{22}$$

$$S_c(p - p_c) = k_m x + \xi_1 \frac{\mathrm{d}x}{\mathrm{d}t} + m_1 \frac{\mathrm{d}^2 x}{\mathrm{d}t^2} - k_{rr} x_r, \tag{23}$$

where Q_1, Q_2 – air flow rates through transducer's chambers, p_e, p – pressure input signals, p_c – corrected pressure signal, depending on the drossel's (13) geometry and on the variable fluidic resistance, S_c – elastic membrane's area, k_m – membrane's elastic constant, μ_1, μ_2 – flow rate co-efficients; ρ – mean air density, β – isotherm compression co-efficient, ξ_1 – viscous friction co-efficient, m_1 – rod+flap ensemble mass, x – rod's displacement, k_{rr} – feed back's spring's elastic constant, x_r – feed back's rod displacement.

- double nozzle-flap hydro-amplifier's (8) equations:

$$Q_3 = \mu_{d_3} \sqrt{2\rho^{-1}}\ \sqrt{p_a - p_L}\ , \tag{24}$$

$$Q_4 = \mu_{d_4} \sqrt{2\rho^{-1}}\, x_1 \sqrt{p_L}\ , \tag{25}$$

$$Q_5 = \mu_{d_5} \sqrt{2\rho^{-1}}\ \sqrt{p_a - p_R}\ , \tag{26}$$

$$Q_6 = \mu_{d_6} \sqrt{2\rho^{-1}}\, x_1 \sqrt{p_R}\ , \tag{27}$$

$$Q_3 - Q_4 = \beta V_L \frac{\mathrm{d}p_L}{\mathrm{d}t} + S_p \frac{\mathrm{d}y}{\mathrm{d}t}, \tag{28}$$

$$Q_5 - Q_6 = \beta V_R \frac{\mathrm{d}p_R}{\mathrm{d}t} - S_p \frac{\mathrm{d}y}{\mathrm{d}t}, \tag{29}$$

$$(p_L - p_R)S_p = m_2 \frac{\mathrm{d}^2 y}{\mathrm{d}t^2} + \xi_2 \frac{\mathrm{d}y}{\mathrm{d}t}, \tag{30}$$

where Q_3, Q_4, Q_5, Q_6 – air flow rates through the double amplifier (8), $\mu_{d_3}, \mu_{d_4}, \mu_{d_5}, \mu_{d_6}$ – flow rate co-efficients, p_a – hydraulic supplying pressure (assumed as constant), p_R, p_L – pressures in servo-amplifier's (9) chambers L and R, V_R – chamber's volume, S_p – slide valve's piston's area, y – slide-valve's displacement, x_1 – flap's displacement $(x_1 = \frac{l_1}{l_2} x)$, m_2 – slide valve's mass, ξ_2 – viscious friction co-efficient.

-servo-amplifier's (9) equations:

$$Q_7 = \mu_7 \sqrt{2\rho^{-1}}\, L(y - v)\sqrt{p_h - p_A}\ , \tag{31}$$

$$Q_8 = \mu_8 \sqrt{2\rho^{-1}}\, L(y - v)\sqrt{p_B}\ , \tag{32}$$

$$Q_7 = \beta V_A \frac{\mathrm{d}p_A}{\mathrm{d}t} + S_A \frac{\mathrm{d}u}{\mathrm{d}t}, \tag{33}$$

$$-Q_8 = \beta V_B \frac{\mathrm{d}p_B}{\mathrm{d}t} - S_B \frac{\mathrm{d}u}{\mathrm{d}t}, \tag{34}$$

where μ_7, μ_8 – flow rate co-efficients, L – servo-amplifier's drag dimension, p_h – hydraulic supplying pressure, p_A, p_B – actuator's (11) chambers A and B pressures; V_A, V_B – A, B chambers' volumes, S_A, S_B – actuator's (11) piston's surface areas, v – inner feed-back rod's (10) displacement, u – rod's displacement.

- actuator's rod equation:

$$p_A S_A - p_B S_B = k_{el} u + \xi_3 \frac{\mathrm{d}u}{\mathrm{d}t} + m_3 \frac{\mathrm{d}^2 u}{\mathrm{d}t}, \tag{35}$$

where k_{el} – actuator's spring's elastic constant, ξ_3 – viscous friction co-efficient, m_3 – piston+rod+flap ensemble's mass .

$$v = \frac{l_1}{l_2} u, \tag{36}$$

$$x_r = \frac{l_4}{l_3} u. \tag{37}$$

System's non-linear mathematical model consists of the equation (20)‘(37); it can be linearized for a steady state operating regime, characterised by the parameters $(p_0, p_{e_0}, Q_{10}, Q_{20}, p_{c0}, ..., p_{A_0}, p_{B_0}, u_0\ )$.

3.2. Linearised model

Expriming the main parameters X as $X = X_0 + \Delta X$, where $X_0 -$ steady state value, $\Delta X -$ static error, $\frac{\Delta X}{X_0} = \bar{X} -$ non-dimensional ratio, one obtains, using the annotations

$$k_{1e} = \mu_d \frac{\pi d_{13}^2}{4} \sqrt{2\rho^{-1}} \, \frac{1}{2\sqrt{p_{e0} - p_{c0}}} = -k_{1c};$$

$$k_{2c} = \mu_d \frac{\pi (d - x_0 \mathrm{tg}\alpha)^2}{4} \sqrt{2\rho^{-1}} \, \frac{1}{2\sqrt{p_{c0}}};$$

$$k_{2c} = \frac{\mu_d \pi}{4}(2x_0 \mathrm{tg}\alpha - d\mathrm{tg}\alpha); k_{3L} = -\left(\frac{\partial Q_3}{\partial p_L}\right)_0 =$$

$$= \mu_d \frac{\pi d_3^2}{4} \sqrt{2\rho^{-1}} \, \frac{2}{\sqrt{p_a - p_{L0}}} = k_{5R};$$

$$k_{4c} = \mu_r d_4 \sqrt{2\rho^{-1}} \, \sqrt{p_L} = -k_{6c};$$

$$k_{4L} = \mu_R d_4 (x_S - x_0) \sqrt{2\rho^{-1}} \, \frac{1}{2\sqrt{p_{L0}}} = k_{6R}, \ \mathrm{D} = \frac{\mathrm{d}}{\mathrm{d}t}, \quad (38)$$

system's linearised form becomes:

$$k_{1e}\Delta p_e - (S_c \mathrm{D} + k_{2x})\Delta x = [\beta V_c \mathrm{D} + (k_{1c} + k_{2c})]\Delta p_c, \quad (39)$$

$$\Delta p_c - \Delta p = \frac{k_m}{S_c}\left(\frac{m_1}{k_m}\mathrm{D}^2 + \frac{\xi_1}{k_m}\mathrm{D} + 1\right)\Delta x - \frac{k_{rr}}{S_c} x_r, \quad (40)$$

$$-(k_{4L} + k_{3L})\Delta p_L + k_{4c}\Delta x = \beta V_L \mathrm{D}\Delta p_L + S_p \mathrm{D}\Delta y, \quad (41)$$

$$-(k_{5R} + k_{6R})\Delta p_R - k_{6x}\Delta x = \beta V_R \mathrm{D}\Delta p_R - S_p \mathrm{D}\Delta y, \quad (42)$$

$$S_p(\Delta p_L - \Delta p_R) = \mathrm{D}(m_2 \mathrm{D} + \xi)\Delta y, \quad (43)$$

$$(\beta V_A \mathbf{D} + k_{7A})\Delta p_A = k_{7y}\Delta y - k_{7v}\Delta v - S_A \mathrm{D}\Delta u, \quad (44)$$

$$(\beta V_B \mathrm{D} + k_{8B})\Delta p_B = -k_{8y}\Delta y + k_{8y}\Delta v + S_B \mathrm{D}\Delta u, \quad (45)$$

$$\Delta p_A - \Delta p_B = \frac{k_{el}}{S}\left(\frac{m_3}{k_{el}}\mathrm{D}^2 + \frac{\xi}{k_{el}}\mathrm{D} + 1\right)\Delta u, \quad (46)$$

which becomes, after the Laplace transformation,

$$k_e \overline{p_e} - k_{cx}(\tau_{cx}s + 1)\bar{x} = (\tau_c s + 1)\overline{p_c}, \quad (47)$$

$$\overline{p_c} - k_p \bar{p} = \frac{1}{k_{xc}}\left(T_1^2 s^2 + 2T_1\omega_1 s + 1\right)\bar{x} - \frac{1}{k_{xr}}\overline{x_r}, \quad (48)$$

$$(\tau_L s + 1)(\overline{p_L} - \overline{p_R}) = k_{Lx}\bar{x} - \tau_p s\bar{y}, \quad (49)$$

$$\overline{p_L} - \overline{p_R} = \frac{1}{k_{Ly}} s(\tau_2 s + 1)\bar{y}, \quad (50)$$

$$(\tau_1 s + 1)(\overline{p_A} - \overline{p_B}) = k_{Ay}\bar{y} - k_{Av}\bar{v} - \tau_A s\bar{u}, \quad (51)$$

$$\overline{p_A} - \overline{p_B} = \frac{1}{k_{Au}}\left(T_3^2 s^2 + 2T_3\omega_3 s + 1\right)\bar{u}, \quad (52)$$

$$\bar{v} = k_{uv}\bar{u}, \ \overline{x_r} = k_{ru}\bar{u}, \quad (53)$$

where $T_c = \frac{\beta V_c}{k_{1c} + k_{2c}}; T_{cx} = \frac{S_c}{k_{2x}}; k_{cx} = \frac{k_{2x}x_0}{(k_{1c} + k_{2c})p_{c0}};$ (54)

$$k_e = \frac{k_{1e}p_{e0}}{(k_{1c} + k_{2c})p_{c0}}; T_1^2 = \frac{m_1}{k_m}; \omega_1 = \frac{\xi}{2m_1}; k_p = \frac{p_0}{p_{c0}} = 1;$$

$$k_{xc} = \frac{p_{c0}}{x_0}\frac{S_c}{k_m}; T_L = \frac{\beta V_L}{k_{Lp}}; k_{Lx} = \frac{2k_{4x}x_0}{p_{L0}k_{Lp}}; \tau_p = \frac{2S_p y_0}{p_{L0}k_{Lp}};$$

$$k_{Ly} = \frac{S_p p_{L0}}{\xi y_0}; T_2 = \frac{m_2}{\xi}; T_A = \frac{\beta V_A}{k_{7A}}; k_{Ay} = \frac{2k_{7y}y_0}{k_{7A}p_{A0}}; k_{xr} =$$

$$= \frac{k_{rr}}{k_{xc}S_c}; k_{Av} = \frac{2k_{7y}v_0}{k_{7A}p_{A0}}; \tau_A = \frac{2S_A u_0}{k_{7A}p_{A0}}; k_{Au} = \frac{Sp_{A0}}{k_{el}u_0}; T_3^2 = \frac{m_3}{k_{el}}$$

Figure 4 presents the non-dimensional linearised system's block-diagram with transfer functions, based on the above determined mathematical model.

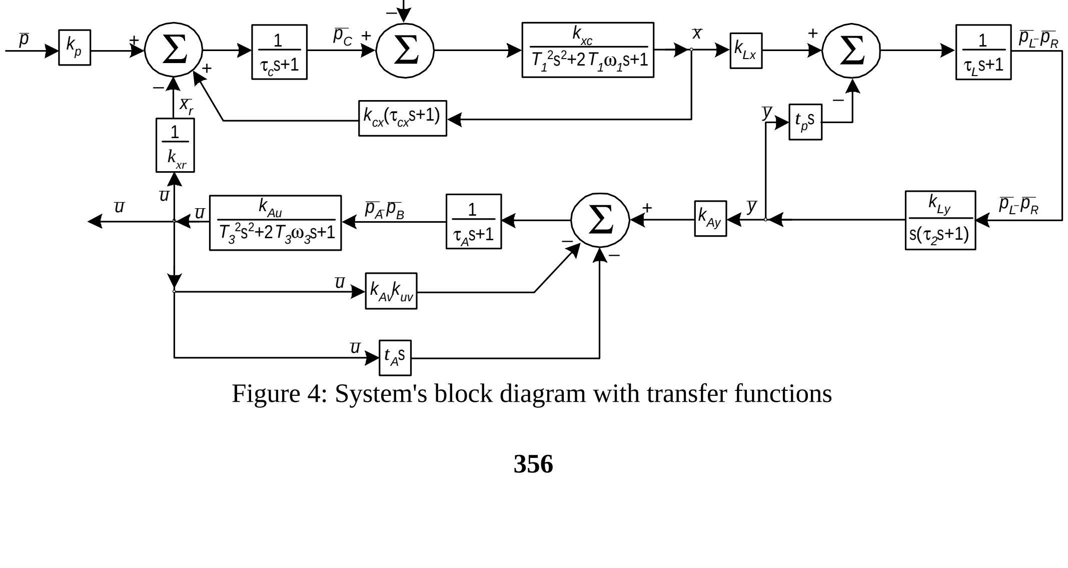

Figure 4: System's block diagram with transfer functions

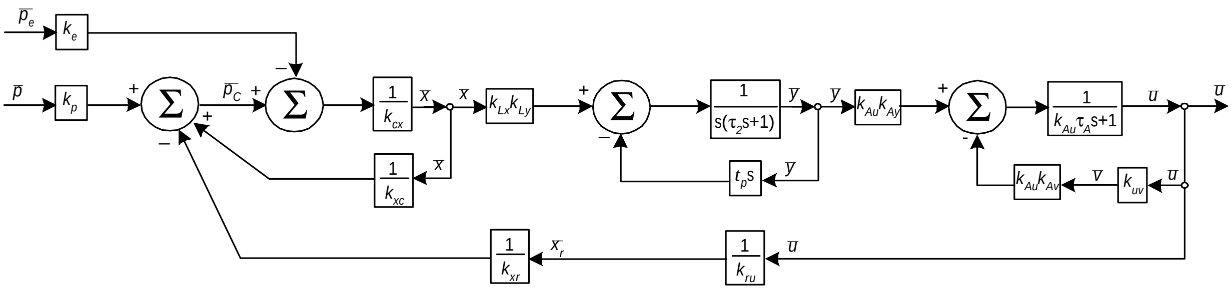

Figure 5: Simplified block diagram with transfer functions

3.3. Non-dimensional, linearised, simplified model

In order to simplify the analysis, one can neglect some terms, which values are small, neglecting the inertial effects, the viscous friction and the fluid's compressibility. That leads to a model's simplified form:

$$k_e\overline{p_e} - k_{cx}(\tau_{cx}s+1)\overline{x} = \overline{p_c}, \quad (55)$$

$$\overline{p_c} - k_p\overline{p} = \frac{1}{k_{xc}}\overline{x} - \frac{1}{k_{xr}}\overline{x_r}, \quad (56)$$

$$\overline{p_L} - \overline{p_R} = k_{Lx}\overline{x} - \tau_p s\overline{y}, \quad (57)$$

$$\overline{p_L} - \overline{p_R} = \frac{1}{k_{Ly}}s\overline{y}, \quad (58)$$

$$\overline{p_A} - \overline{p_B} = k_{Ay}\overline{y} - k_{Av}\overline{v} - \tau_A s\overline{u}, \quad (59)$$

$$\overline{p_A} - \overline{p_B} = \frac{1}{k_{Au}}\overline{u}, \quad (60)$$

$$\overline{v} = k_{uv}\overline{u},\ \overline{x_r} = k_{ru}\overline{u}. \quad (61)$$

System's equivalent form becomes

$$k_e\overline{p_e} - k_p\overline{p} = (A_3s^3 + A_2s^2 + A_1s + A_0)\overline{u}, \quad (62)$$

where $A_3 = \frac{(1+k_{xc}k_{cx})\tau_2\tau_R}{k_{xc}k_{Lx}k_{Ly}k_{Ay}}$, $A_0 = \frac{k_{ru}}{k_{xr}}$,

$$A_2 = \frac{(1+k_{xc}k_{cx})\tau_2(1+k_{Au}k_{Av}k_{uv})}{k_{xc}k_{Lx}k_{Ly}k_{Au}k_{Ay}} + \frac{(1+k_{xc}k_{cx})\tau_R(1+\tau_p)}{k_{xc}k_{Lx}k_{Ly}k_{Ay}},$$

$$A_1 = \frac{(1+k_{xc}k_{cx})(1+\tau_p)(1+k_{Au}k_{Av}k_{uv})}{k_{xc}k_{Lx}k_{Ly}k_{Au}k_{Ay}}. \quad (63)$$

4. SYSTEM'S STABILITY AND QUALITY

Based on the above presented simplified model, one can define two transfer functions for the system, with respect to the flight regime $H_{HV}(s) = \frac{\overline{u}(s)}{\overline{p}(s)}$, respectively to the engine's operating regime $H_n(s) = \frac{\overline{u}(s)}{\overline{p_e}(s)}$. Both of them have the same characteristic polynom, which co-efficients are given by formulas (63).

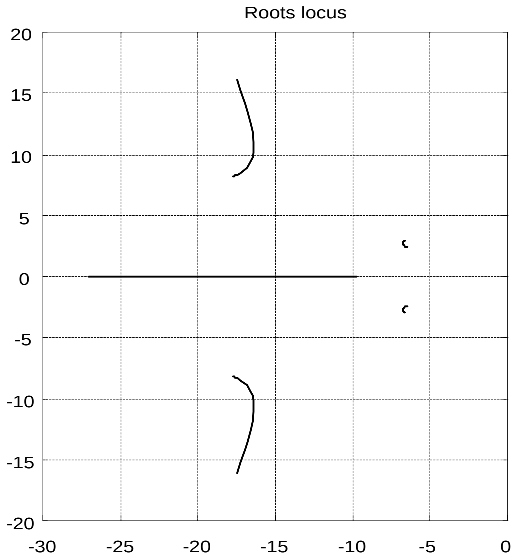

Figure 6: Characteristic polynom's roots locus

Considering a constant supersonic flight regime (H=10000 m, V=2000 km/h) p =const., $\overline{p} = 0$, one studies only the second transfer function, $H_n(s)$, for the interval of rotation speed n=(40% ‘ 100%)n_{max}.

In order to study the system's stability, one has performed a root-locus study for the characteristic polynom; it results a diagram (see figure 6), which shows that the polynom has three roots, a real negative one and two complex conjugate, which real parts are also negative, as figure 6 shows. Therefore, in any case, for any engine operating regime, the studied system is stable. The same conclusion is revealed by the frequency characteristics (ampli- tude-frequency and phase-frequency), shown in fig. 7.

System's quality is presented by the indiceal function, the system's step response (figure 8), for three engine operating regimes (R1- minimum $n = 0.4n_{max}$, R2- intermediate/cruise $n = 0.75n_{max}$ and R3- maximum $n = n_{max}$); system's behaviour is shown by the three curves, which show a small periodic stabilisation of the flaps'opening, with an initial overlap. The overlap isn't bigger than 3.5%, it has maximum value for the R1 regime and diminishes by the rotation speed increasing, beein minimum for R3 regime; the stabilising time is about 3 ‘ 3.5 s, a little bigger for the same R1 regime, which is the worse operating regime.

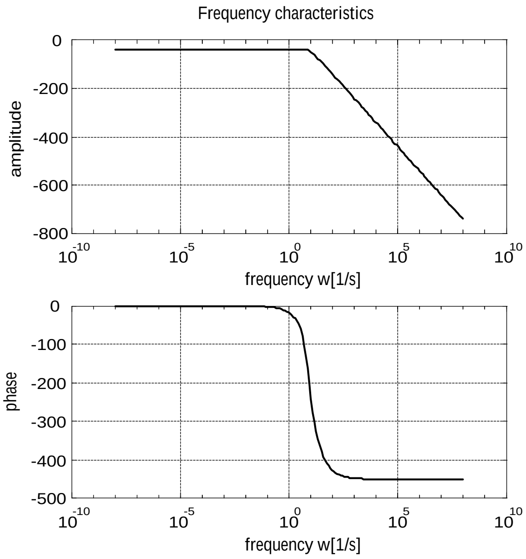

Figure 7: System's frequency characteristics

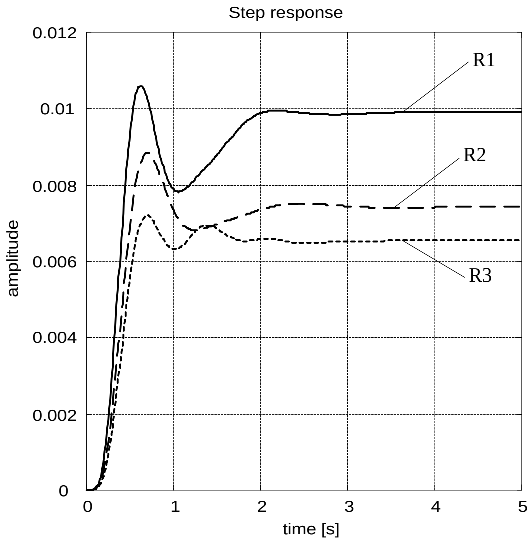

Figure 8: System's step response

5. CONCLUSIONS

One has studied an automatic supersonic intake control system, based on the air bleeding control through the anti-stall flaps' positioning. A possible command law was established, with respect to the static or total pressure ratio, which involves the rear intake's pressure (p_1 or p_e). A stability study was performed, as well as a system's time behaviour simulation (step response), which gave some useful information about system's quality. Similary conclusions can be obtained for the system's Dirac impulse response.

Although, engine's rotation speed variation can't be realised as "step input", because of engines control system, which realizes a ramp variation of the injected fuel flow rate and, consequently, a similar rotation speed variation, which involves a nearly linear behavior for the air bleeding flaps' positioning (fig. 9).

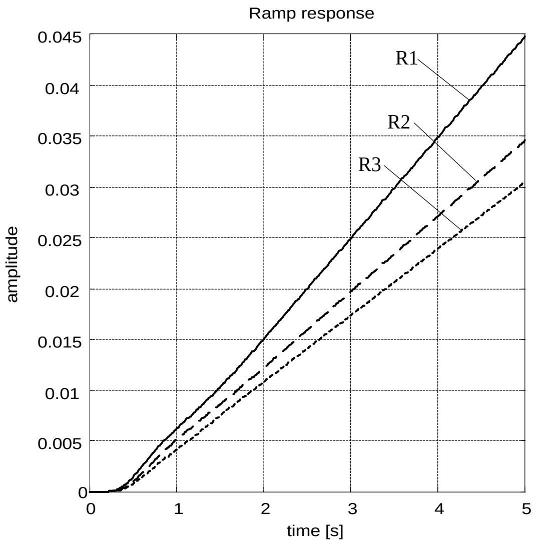

Figure 9: System's ramp response

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