A MODEL FOR AERODYNAMICAL DATA STRUCTURE; GRAPHICAL INTERFACE AND USER'S FACILITIES

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DOI: 10.13111/2066-8201.2010.2.1.9

Abstract
This model defines the structure and applicability of aero dynamical complex data (up to four dimensions without flap influence which is separate considered) in steady states calculus for different configurations and optional cases (ground effect, asymmetrical propulsion (one of engines out) as well as in dynamic simulations.
They user is offered many facilities of data entry, correction and graphical view. The punctual values of dimensional parameters for each coefficient are automaticaly checked for the string strictly increased or decreased specific feature.

1-Introduction – general form for input data

In the beginning, the graphical interface will display the form of the aerodynamic coefficients, the hinge moments coefficients and the thrust data, as following:
The coefficient of the drag force (expressed in the aerodynamic axes system):

$$CD = CD\_basic + \Delta CD\_elevator + \Delta CD\_flap + \Delta CD\_elevator\_flap + \\ + \Delta CD\_airbrakes + \Delta CD\_gear + \Delta CD\_groundEffect$$

The coefficient of the lift force (expressed in the aerodynamic axes system):

$$CL = CL\_basic + \Delta CL\_elevator + \Delta CL\_flap + \Delta CL\_airbrakes + \Delta CL\_gear + \\ + \frac{c}{2\cdot V}\cdot\left[\left(CL_q + \Delta CL_q\_flap\right)\cdot q + \left(CL_{\dot{\alpha}} + \Delta CL_{\dot{\alpha}}\_flap\right)\cdot\dot{\alpha}\right] + \Delta CL\_groundEffect + \\ + \Delta CL\_propEffect + \Delta CL_{\dot{\alpha}}\_propEffect\cdot\dot{\alpha} + \Delta CL_{\dot{q}}\_propEffect\cdot\dot{q}$$

The coefficient of the side force (expressed in the aircraft body system):

$$CY = CY\_basic + \Delta CY\_rudder + \Delta CY\_aileron + \Delta CY\_flap + \Delta CY\_aileron\_flap + \\ + \Delta CY\_rudder\_flap + \frac{b}{2\cdot V}\cdot\left[\left(CY_p + \Delta CY_p\_flap\right)\cdot p + \left(CY_r + \Delta CY_r\_flap\right)\cdot r\right] + \\ + \Delta CY\_propEffect$$

The coefficient of the rolling moment (expressed in the aircraft body system):

$$Cl = Cl\_basic + \Delta Cl\_rudder + \Delta Cl\_aileron + \Delta Cl\_flap + \Delta Cl\_rudder\_flap + \\ + \Delta Cl\_aileron\_flap + \frac{b}{2\cdot V}\cdot\left[\left(Cl_p + \Delta Cl_p\_flap\right)\cdot p + \left(Cl_r + \Delta Cl_r\_flap\right)\cdot r\right] + \\ + \Delta Cl\_propEffect + \Delta Cl_{\dot{r}}\_propEffect\cdot\dot{r}$$

The coefficient of the pitching moment (expressed in the aircraft body system):

$$CM = CM\_basic + \Delta CM\_elevator + \Delta CM\_flap + \Delta CM\_airbrakes + \Delta CM\_gear +$$
$$+ \frac{c}{2 \cdot V} \cdot \left[\left(CM_q + \Delta CM_q\_flap \right) \cdot q + \left(CM_{\dot{\alpha}} + \Delta CM_{\dot{\alpha}}\_flap \right) \cdot \dot{\alpha} \right] + \Delta CM\_propEffect +$$
$$+ \Delta CM_{\dot{\alpha}}\_propEffect \cdot \dot{\alpha} + \Delta CM_{\dot{q}}\_propEffect \cdot \dot{q}$$

The coefficient of the yawing moment (expressed in the aircraft body system):

$$CN = CN\_basic + \Delta CN\_rudder + \Delta CN\_aileron + \Delta CN\_flap + \Delta CN\_aileron\_flap +$$
$$+ \Delta CN\_rudder\_flap + \frac{b}{2 \cdot V} \cdot \left[\left(CN_p + \Delta CN_p\_flap \right) \cdot p + \left(CN_r + \Delta CN_r\_flap \right) \cdot r \right] +$$
$$+ \Delta CN\_propEffect + \Delta CN_{\dot{p}}\_propEffect \cdot \dot{p} + \Delta CN_{\dot{r}}\_propEffect \cdot \dot{r}$$

The coefficient of the hinge moment for elevator:

$$CHE = CHE\_basic + \Delta CHE\_flap + \Delta CHE\_elevator + \Delta CHE\_tab$$

The coefficient of the hinge moment for ailerons:

$$CHA = CHA\_basic + \Delta CHA\_flap + \Delta CHA\_aileron + \Delta CHA\_tab$$

The coefficient of the hinge moment for rudder:

$$CHR = CHR\_basic + \Delta CHR\_flap + \Delta CHR\_rudder + \Delta CHR\_tab$$

Depending of the user, the ENGINE value of thrust can be function of true_airspeed, altitude, and engine control.

2-Description of the aerodynamic coefficients components

NOTE 1: Because of the way the database is structured, each component of aerodynamic coefficients can have up to four dimensions (number of dimensions, dimensional parameters and parameter positioning chosen by the user).

$CD\_basic = f(\alpha, \beta, Mach, ih)$; $CL\_basic = f(\alpha, \beta, Mach, ih)$;

$CM\_basic = f(\alpha, \beta, Mach, ih)$; these are the basis of the longitudinal coefficients (drag, lift, pitching moment) in the clean configuration (flaps and landing gear retracted).These coefficients can be entered to the database, depending on the user, with a number of up to four dimensions (alpha=incidence angle, β= sideslip angle, Mach number, ih=stabilizer deflection angle)

$\Delta CD\_elevator = f(\alpha, Mach, ih, \delta e)$; $\Delta CL\_elevator = f(\alpha, Mach, ih, \delta e)$;

$\Delta CM\_elevator = f(\alpha, Mach, ih, \delta e)$; these coefficients represent the variation given by the elevator deflection :

$\Delta CD\_elevator = CD(\alpha, Mach, ih, \delta e) - CD(\alpha, Mach, ih, \delta e = 0)$ and similarly for the others. In the database these coefficients can be characterized (depending on the user) by up to four dimensions.

$\Delta CD\_flap = f(\alpha, \beta, flap)$ $\Delta CL\_flap = f(\alpha, \beta, flap)$ $\Delta CM\_flap = f(\alpha, \beta, flap)$

these coefficients represent the variations due to the flap deflection (with all (δe,δa, δr) commands in neutral position/zero):

$\Delta CD\_flap = CD(\alpha, \beta, flap) - CD(\alpha, \beta, flap = 0)$ and likewise for the rest.

In the database separate tables appear for flap 1 and flap 2, as a function of the flap deflection angle, these being characterized (depending on the user) by two dimensions (α,β).

$\Delta CD\_elevator\_flap = f(\alpha, flap, ih, \delta e)$

$\Delta CL\_elevator\_flap = f(\alpha, flap, ih, \delta e)$ $\Delta CM\_elevator\_flap = f(\alpha, flap, ih, \delta e)$

These coefficients represent the variation due to the flap deflection :

$\Delta CD\_elevator\_flap = CD(\alpha, flap, ih, \delta e) - CD(\alpha, flap = 0, ih, \delta e)$ and similarly for the others. In the database separate tables appear for flap 1 and flap 2, as a function of the flap deflection angle, these being characterized (depending on the user) by three dimensions (α,ih, ,δe).

$\Delta CD\_gear = f(\alpha, gear\_position)$ This coefficient represents the CD_basic variation due to the landing gear extension. In the database the coefficient can appear (up to the user) in a one-dimensional form depending on α (the coefficient implicitly exists or not, depending on the L/G position: extended or retracted).

$\Delta CD\_airbrakes = f(\alpha, Mach, \delta_{ab})$, $\Delta CL\_airbrakes = f(\alpha, Mach, \delta_{ab})$,

$\Delta CM\_airbrakes = f(\alpha, Mach, \delta_{ab})$ These coefficients represent the variation of the basic longitudinal coefficients which is due to the utilization of the air-brakes and similarly for the others. In the database the coefficients can have three dimensions (depending on the user): α, Mach, deflection of the air-brakes.

$CL_{\dot{\alpha}} = f(\alpha, Mach)$, $CM_{\dot{\alpha}} = f(\alpha, Mach)$ These coefficients represent the variation of the basic longitudinal coefficients which is due to the attack angle variation speed in clean configuration (without flaps and air-brakes and L/G retracted). Up to the user, these coefficients can appear in the database in a twodimensional form, depending on the attack angle and Mach value.

$CL_q = f(\alpha, Mach)$, $CM_q = f(\alpha, Mach)$ These coefficients represent the basic longitudinal coefficients variation with the pitching speed , in clean configuration. Up to the user, these coefficients can appear in the database in a twodimensional form, depending on the attack angle and Mach value. The drag coefficient variation with the pitching speed is neglected.

$\Delta CL_{\dot{\alpha}}\_flap = f(\alpha, flap)$, $\Delta CM_{\dot{\alpha}}\_flap = f(\alpha, flap)$ These coefficients represent the α derivatives variation of the basic longitudinal coefficients which is due to the flap deflection :

$\Delta CL_{\dot{\alpha}}\_flap = CL_{\dot{\alpha}}(\alpha, flap) - CL_{\dot{\alpha}}(\alpha, flap = 0)$ and similarly for the other. Depending on the user, in the database these coefficients can be attack angle and flap deflection-responsive.

$\Delta CL_q\_flap = f(\alpha, flap)$, $\Delta CM_q\_flap = f(\alpha, flap)$ These coefficients represent the variation of the q derivatives of the longitudinal coefficients which is due to the flap deflection. Depending on the user, in the database these coefficients can be attack angle and flap deflection-responsive.

$CY\_basic = f(\alpha, \beta, Mach)$, $Cl\_basic = f(\alpha, \beta, Mach)$, $CN\_basic = f(\alpha, \beta, Mach)$ These coefficients are the basic side directional coefficients (for the side force , roll and yaw moments) calculated for all void control deflections. It is considered that the elevator and stabilizer deflections do not modify these coefficients.

$\Delta CY\_flap = f(\alpha, \beta, flap)$, $\Delta Cl\_flap = f(\alpha, \beta, flap)$, $\Delta CN\_flap = f(\alpha, \beta, flap)$ These coefficients represent the variation of the basic side directional coefficients (with zero/neutral commands on ailerons and rudder) which is due to the flap utilization :
$\Delta CY\_flap = CY(\alpha, \beta, flap) - CY(\alpha, \beta, flap = 0)$ and similarly for the others. Depending on the user, in the database these coefficients can be attack and side-slip angle – responsive.

$\Delta CY\_aileron = f(\alpha, \beta, Mach, \delta_a)$ $\Delta Cl\_aileron = f(\alpha, \beta, Mach, \delta_a)$
$\Delta CN\_aileron = f(\alpha, \beta, Mach, \delta_a)$ These coefficients represent the variation of the basic side-directional coefficients which is due to the ailerons deflection :
$\Delta CY\_aileron = CY(\alpha, \beta, Mach, \delta_a) - CY(\alpha, \beta, \delta_a = 0)$ and similarly for the others. Depending on the user, in the database these coefficients can be Mach value, ailerons deflection, attack and side-slip angle-responsive.

$\Delta CY\_rudder = f(\alpha, \beta, Mach, \delta_r)$ $\Delta Cl\_rudder = f(\alpha, \beta, Mach, \delta_r)$
$\Delta CN\_rudder = f(\alpha, \beta, Mach, \delta_r)$ These coefficients represent the variation of the basic side-directional coefficients which is due to the rudder deflection :
$\Delta CY\_rudder = CY(\alpha, \beta, Mach, \delta_r) - CY(\alpha, \beta, \delta_r = 0)$ and similarly for the others. Depending on the user, in the database these coefficients can be Mach value, attack, side-slip angle and rudder deflection-responsive. The effects of the ailerons and rudder are always considered decoupled, so that:

$$CY(\alpha, \beta, Mach, \delta_a, \delta_r) = CY(\alpha, \beta, Mach, \delta_a = 0, \delta_r) + CY(\alpha, \beta, Mach, \delta_a, \delta_r = 0)$$

$\Delta CY\_aileron\_flap = f(\alpha, \beta, flap, \delta_a)$, $\Delta Cl\_aileron\_flap = f(\alpha, \beta, flap, \delta_a)$,
$\Delta CN\_aileron\_flap = f(\alpha, \beta, flap, \delta_a)$ These coefficients represent:
$\Delta CY\_aileron\_flap = CY(\alpha, \beta, flap, \delta_a) - CY(\alpha, \beta, flap, \delta_a = 0)$ and similarly for the others. Depending on the user, in the database these coefficients can be function of α, β and ailerons deflection, with separate tables for the flap positions.

$\Delta CY\_rudder\_flap = f(\alpha, \beta, flap, \delta_r)$, $\Delta Cl\_rudder\_flap = f(\alpha, \beta, flap, \delta_r)$,
$\Delta CN\_rudder\_flap = f(\alpha, \beta, flap, \delta_r)$ These coefficients represent :

$\Delta CY\_rudder\_flap = CY(\alpha,\beta, flap,\delta_r) - CY(\alpha,\beta, flap,\delta_r = 0)$ and similarly for the others. Depending on the user, in the database these coefficients can be function of α, β and ailerons deflection, with separate tables for the flap positions.

$CY_p = f(\alpha, Mach)$, $Cl_p = f(\alpha, Mach)$, $CN_p = f(\alpha, Mach)$ These coefficients represent the variation of the basic side-directional coefficients in clean configuration, with roll speed.

$\Delta CY_p\_flap = f(\alpha, flap)$, $\Delta Cl_p\_flap = f(\alpha, flap)$, $\Delta CN_p\_flap = f(\alpha, flap)$
These coefficients represent the variation of the “p”side-directional derivatives which is due to the flap deflection :
$\Delta CY_p\_flap = CY_p(\alpha, Mach, flap) - CY_p(\alpha, Mach, flap = 0)$ and similarly for the others.

$CY_r = f(\alpha, Mach)$, $Cl_r = f(\alpha, Mach)$, $CN_r = f(\alpha, Mach)$ These coefficients represent the variation of the side-directional coefficients in clean configuration, with yaw rate.

$\Delta CY_r\_flap = f(\alpha, flap)$, $\Delta Cl_r\_flap = f(\alpha, flap)$, $\Delta CN_r\_flap = f(\alpha, flap)$
These coefficients represent the variation of the “r”side- directional coefficients which is due to the flap deflection:
$\Delta CY_r\_flap = CY_r(\alpha, Mach, flap) - CY_r(\alpha, Mach, flap = 0)$ and similarly for the others.

3-Details about the data entering method (the witness file)

The data are written in “txt” file (witness file). This file can be accessed in graphical interface for visualization or correction; a method of data graphical validation/control should be available (the data are marked X,Y and the diagram is visualized together with the derivative, if need be, using the calculation routine algorithm of spline cubical interpolation). **The witness file** shall have the following structure:

-**Name** of the aerodynamic datum; configuration (clean, flap, air-brakes, landing gear, ground effects, propulsion effect); other information (axes system for which the data are valid, calculation centering,…)
-**Dimensions**[up to 4, in order: [dimens_4=number of points], [dimens_3], [dimens_2], [dimens_1], where 1,2,3,4 can be one of the parameters: ALPHA(incidence angle expressed in degrees), ALFA_ELEVATOR(elevator incidence angle expressed in degrees), BETA(side-slip angle expressed in degrees), MACH(Mach number), IH(stabilizer deflection expressed in degrees), controls(deflection angle- expressed in degrees -for controls (elevator (E_DELTA), ailerons(A_DELTA), rudder(R_DELTA), elevator trimmer(E_TAB_DELTA), aileron trimmer(A_TAB_ DELTA), rudder trimmer(R_TAB_ DELTA)), TRUE_AIRSPEED(true speed expressed in m/s), ALTITUDE(altitude expressed in m), CT(thrust control: 0 for ralenti, 1 for full operation), LIFT(lift force coefficient), HAT(dimensional quantity utilized for the ground effect)]; the dimensions are chosen

(written) in order starting with dimens_1 and the user can add other parameters for aerodynamical coefficients dependences (the rest up to 32).
NOTE 2: The number of points for any chosen dimension is at least 2 and at most 20; if one of the aerodynamic data is constant, then the dimension field shall show [NONE].
If the user has chosen 4 dimensions, only dimens_4 will be shown including the parameter information and the number of points, the other dimensions being given by the parameter information. If the user has chosen 3 dimensions, only dimens_3 will be shown including the parameter information and the number of points, the other dimensions being given by the parameter information.
-Punctual values (all) dimens_4 (if they don't exist, one moves on to the next parameter); (Marcher explanation_NOTE 3);
-[dimens_3=number of points] (if it doesn't exist , one moves on to the next parameter);
-Punctual values (all) dimens_3 (if they don't exist , one moves on to the next parameter); (Marcher explanation_NOTE 2);
-[dimens_2=number of points], [dimens_1=number of points];
-Punctual values dimens_2;
-Punctual values dimens_1;
-Aerodynamic datum value for chosen dimensions (each row is obtained by incrementing in order the dimens_1 and dimens_2);
-If dimens_3 exists, the following value of dimens_3 is written and one resumes from (Marcher explanation_NOTE 2) until the completion of the values of dimens_3;
-If dimens_4 exists, the following value of dimens_4 is written and one resumes from (Marcher explanation_NOTE 3) until the completion of the values of dimens_4;
NOTE 3: When incrementing dimens_3, sign # will be written on a row and when incrementing dimens_4 the sign ## will be written. Between the aerodynamic data, 2 empty rows shall be left.
NOTE 4: Initially, before the user uploads the data, each component of the aerodynamic coefficients has the value ZERO. The user should be prompted not to utilize the value V=0 (implicitly Mach=0) when choosing his calculus options and to enter values for the component *ΔCM_elevator* (which is sensitive to the mathematical solving algorithm; this component shall be different from 0).

4-User input data sample (many dimensions for data in "A_D_CoeffData.txt" file)

```
Engine
[CT=3]  [ALTITUDE]  [TRUE_AIRSPEED]
0.00  0.90  1.00
[ALTITUDE=6]  [TRUE_AIRSPEED=11]
0  1524  3048  4572  6096  7620
0  10  20  30  40  50  60  80  100  120  140
0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0
0.90
[ALTITUDE=6]  [TRUE_AIRSPEED=11]
```

0 1524 3048 4572 6096 7620
0 10 20 30 40 50 60 80 100 120 140
9502 8896 8151 7374 6625 5935 5320 4303 3540 2971 2526
8763 8370 7783 7098 6423 5797 5227 4276 3540 2985 2556
7572 7276 6799 6216 5650 5127 4648 3863 3253 2825 2486
6486 6266 5871 5373 4891 4443 4031 3357 2833 2460 2165
5517 5355 5033 4611 4203 3822 3471 2896 2452 2129 1872
4645 4529 4265 3911 3566 3241 2943 2454 2081 1807 1589
1.00
[ALTITUDE=6] [TRUE_AIRSPEED=11]
0 1524 3048 4572 6096 7620
0 10 20 30 40 50 60 80 100 120 140
9502 8896 8151 7374 6625 5935 5320 4303 3540 2971 2526
8765 8370 7783 7098 6423 5797 5227 4276 3540 2985 2556
7630 7354 6897 6316 5749 5220 4733 3923 3284 2820 2442
6522 6357 5984 5487 5001 4549 4134 3447 2915 2533 2229
5525 5427 5122 4703 4291 3906 3551 2968 2515 2185 1920
4647 4562 4310 3966 3625 3302 2998 2505 2126 1848 1627

CY_basic lisa body system
[BETA=3] [ALPHA=3]
-20 0 20
0 5 10
0.0000 -0.0690 -0.1381
0.0000 -0.0735 -0.1470
0.0000 -0.0690 -0.1381

CLAP lisa wind system
[NONE]
-2.8170

5-The tables of the required data

After loading the witness file, the graphical interface should show (in two separate panels: one for the necessary data for the equilibrium state calculation and the other for the dynamic simulation) which data are loaded in this file (data contained in the file appear on a differently colored background).

<u>The Table of the required data for the equilibrium states calculation</u> shall contain two <u>categories</u>: main data and auxiliary data.

Main data :

-for CD : CD_basic, ΔCD_elevator ;
-for CL : CL_basic, ΔCL_elevator, CL_q ;
-for CY : CY_basic, ΔCY_rudder, ΔCY_aileron, CY_p, CY_r ;
-for Cl : Cl_basic, ΔCl_rudder, ΔCl_aileron, Cl_p, Cl_r ;
-for CM : CM_basic, ΔCM_elevator, CM_q ;
-for CN : CN_basic, ΔCN_rudder, ΔCN_aileron, CN_p, CN_r ;
-for CHE : CHE_basic, ΔCHE_elevator;
-for CHA : CHA_basic, ΔCHA_aileron;

-for CHR : CHR_basic, ΔCHR_rudder;
-for propulsion : engine

Auxiliary data:
-for CD : ΔCD_flap1, ΔCD_flap2, ΔCD_elevator_flap1, ΔCD_elevator_flap2, ΔCD_airbrakes, ΔCD_gear, ΔCD_groundEffect;
-for CL : ΔCL_flap1, ΔCL_flap2, ΔCL_airbrakes, ΔCL_gear, Δ CL_q_flap1, ΔCL_q_flap2, ΔCL_groundEffect, ΔCL_propEffect_0_1, ΔCL_propEffect_1_0, ΔCL_propEffect_1_1;
-for CY : ΔCY_flap1, ΔCY_flap2, ΔCY_aileron_flap1, ΔCY_aileron_flap2, ΔCY_rudder_flap1, ΔCY_rudder_flap2, ΔCY_p_flap1, ΔCY_p_flap2, ΔCY_r_flap1, ΔCY_r_flap2, ΔCY_propEffect_0_1, ΔCY_propEffect_1_0, ΔCY_propEffect_1_1;
-for Cl : ΔCl_flap1, ΔCl_flap2, ΔCl_aileron_flap1, ΔCl_aileron_flap2, ΔCl_rudder_flap1, ΔCl_rudder_flap2, ΔCl_p_flap1, ΔCl_p_flap2, ΔCl_r_flap1, ΔCl_r_flap2, ΔCl_propEffect_0_1, ΔCl_propEffect_1_0, ΔCl_propEffect_1_1;
-for CM : ΔCM_flap1, ΔCM_flap2, ΔCM_airbrakes, ΔCM_gear, ΔCM_q_flap1, ΔCM_q_flap2, ΔCM_propEffect_0_1, ΔCM_propEffect_1_0, ΔCM_propEffect_1_1;
-for CN : ΔCN_flap1, ΔCN_flap2, ΔCN_aileron_flap1, ΔCN_aileron_flap2, ΔCN_rudder_flap1, ΔCN_rudder_flap2, ΔCN_p_flap1, ΔCN_p_flap2, ΔCN_r_flap1, ΔCN_r_flap2, ΔCN_propEffect_0_1, ΔCN_propEffect_1_0, ΔCN_propEffect_1_1;
-for CHE : ΔCHE_flap1, ΔCHE_flap2, ΔCHE_tab, elevator_gearing;
-for CHA : ΔCHA_flap1, ΔCHA_flap2, ΔCHA_tab, aileron_gearing;
-for CHR : ΔCHR_flap1, ΔCHR_flap2, ΔCHR_tab, rudder_gearing;
Table of the simulation required data :
-for CL : $CL_{\dot{\alpha}}$, $\Delta CL_{\dot{\alpha}}\_flap1$, $\Delta CL_{\dot{\alpha}}\_flap2$, $\Delta CL_{\dot{\alpha}}\_propEffect\_0\_1$, $\Delta CL_{\dot{\alpha}}\_propEffect\_1\_0$, $\Delta CL_{\dot{\alpha}}\_propEffect\_1\_1$, $\Delta CL_{\dot{q}}\_propEffect\_0\_1$, $\Delta CL_{\dot{q}}\_propEffect\_1\_0$, $\Delta CL_{\dot{q}}\_propEffect\_1\_1$;
-for CY : -
-for Cl : $\Delta CL_{\dot{r}}\_propEffect\_0\_1$, $\Delta CL_{\dot{r}}\_propEffect\_1\_0$, $\Delta CL_{\dot{r}}\_propEffect\_1\_1$;
-for CM : $CM_{\dot{\alpha}}$, $\Delta CM_{\dot{\alpha}}\_flap1$, $\Delta CM_{\dot{\alpha}}\_flap2$, $\Delta CM_{\dot{\alpha}}\_propEffect\_0\_1$, $\Delta CM_{\dot{\alpha}}\_propEffect\_1\_0$, $\Delta CM_{\dot{\alpha}}\_propEffect\_1\_1$, $\Delta CM_{\dot{q}}\_propEffect\_0\_1$, $\Delta CM_{\dot{q}}\_propEffect\_1\_0$, $\Delta CM_{\dot{q}}\_propEffect\_1\_1$;
-for CN : $\Delta CN_{\dot{p}}\_propEffect\_0\_1$, $\Delta CN_{\dot{p}}\_propEffect\_1\_0$, $\Delta CN_{\dot{p}}\_propEffect\_1\_1$, $\Delta CN_{\dot{r}}\_propEffect\_0\_1$, $\Delta CN_{\dot{r}}\_propEffect\_1\_0$, $\Delta CN_{\dot{r}}\_propEffect\_1\_1$.

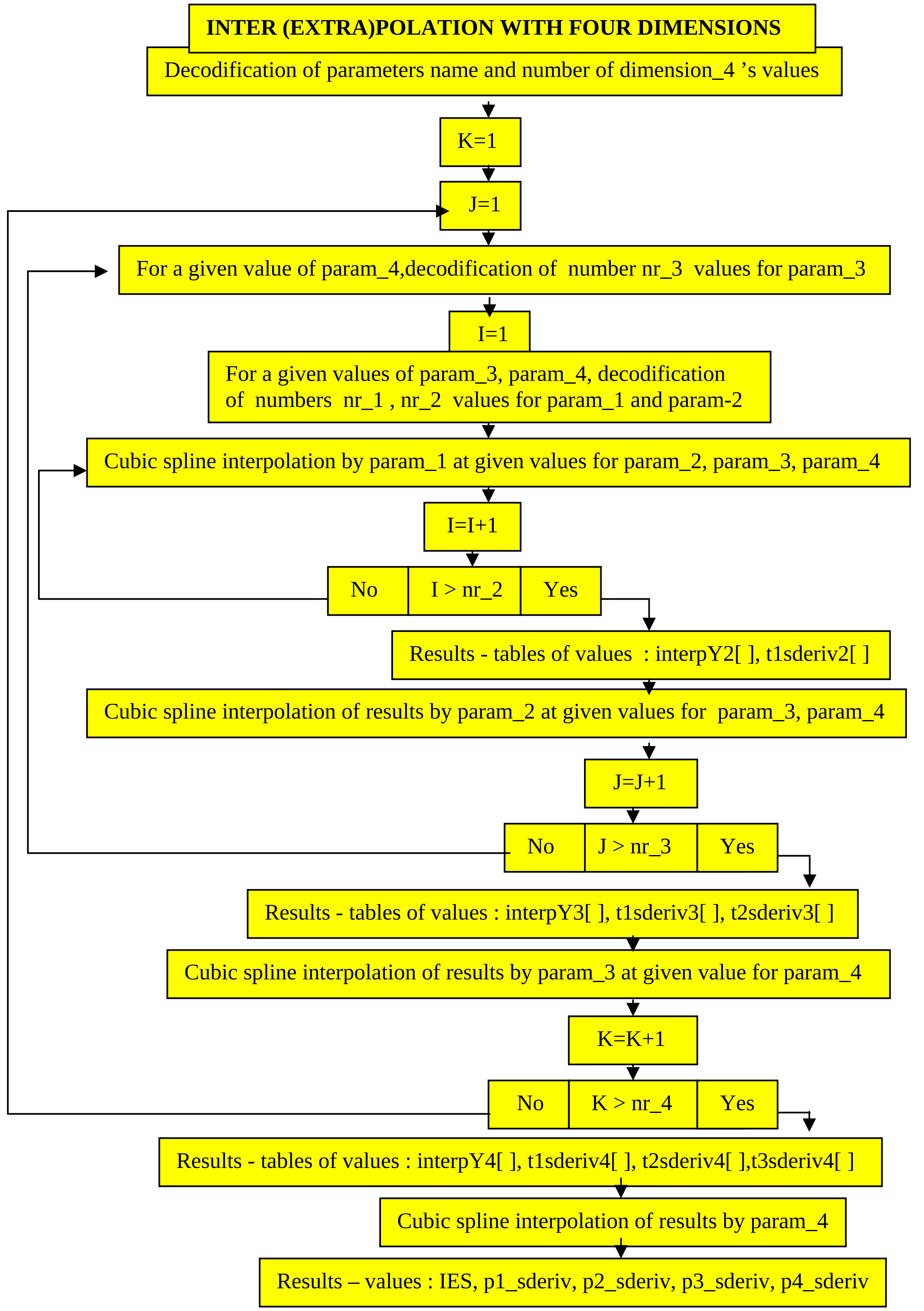
INTER (EXTRA)POLATION WITH FOUR DIMENSIONS
Decodification of parameters name and number of dimension_4 's values
K=1
J=1
For a given value of param_4,decodification of number nr_3 values for param_3
I=1
For a given values of param_3, param_4, decodification of numbers nr_1 , nr_2 values for param_1 and param-2
Cubic spline interpolation by param_1 at given values for param_2, param_3, param_4
I=I+1
No
I > nr_2
Yes
Results - tables of values : interpY2[ ], t1sderiv2[ ]
Cubic spline interpolation of results by param_2 at given values for param_3, param_4
J=J+1
No
J > nr_3
Yes
Results - tables of values : interpY3[ ], t1sderiv3[ ], t2sderiv3[ ]
Cubic spline interpolation of results by param_3 at given value for param_4
K=K+1
No
K > nr_4
Yes
Results - tables of values : interpY4[ ], t1sderiv4[ ], t2sderiv4[ ],t3sderiv4[ ]
Cubic spline interpolation of results by param_4
Results – values : IES, p1_sderiv, p2_sderiv, p3_sderiv, p4_sderiv

Fig. 1

Explanations note for "Inter(extra)polation with four dimensions"

interpY2[ ] = values table = inter(extra)polation function of parameter_1 for each line corresponding to parameter_2;
interpY3[ ] = values table = inter(extra)polation function of parameter_1 and parameter_2;
interpY4[ ] = values table = inter(extra)polation function of parameter_1, parameter_2, parameter_3;
t1sderiv2[ ] = values table = for each parameter_2 value, derivative by parameter_1 at his given value for interpolation;
t1sderiv3[ ] = values table = for each parameter_3 value, derivative, by parameter_1, at given values of parameter_1 and parameter_2;
t2sderiv3[ ] = values table = for each parameter_3 value, derivative, by parameter_2, at given values of parameter_1 and parameter_2;
t1sderiv4[ ] = values table = for each parameter_4 value, derivative, by parameter_1, at given values of parameter_1 , parameter_2 and parameter_3;
t2sderiv4[ ] = values table = for each parameter_4 value, derivative, by parameter_2, at given values of parameter_1 , parameter_2 and parameter_3;
t3sderiv4[ ] = values table = for each parameter_4 value, derivative, by parameter_3, at given values of parameter_1 , parameter_2 and parameter_3;
IES = the inter(extra)polation value at given values of parameter_1 , parameter_2 , parameter_3, parameter_4;
p1_sderiv = the derivative value by parameter_1 at given values for parameter_1 , parameter_2 , parameter_3, parameter_4;
p2_sderiv = the derivative value by parameter_2 at given values for parameter_1 , parameter_2 , parameter_3, parameter_4;
p3_sderiv = the derivative value by parameter_3 at given values for parameter_1 , parameter_2 , parameter_3, parameter_4;
p4_sderiv = the derivative value by parameter_4 at given values for parameter_1 , parameter_2 , parameter_3, parameter_4.

The extrapolation is made when the parameter calculus value exceeds the interval of data base, but it is in user's defined limits (two-dimensional table "lista[ ][ ]" show MIN and MAX values for each parameter).
In conformity with the user's option, the dates for "flap" are in separate tables (for two flap positions).

6-User's graphical interface facilities

The graphical interface shall also analyze the correctness of the witness file (if the declared dimensions are respected and the dimensional parameters values are monotone (specific and increasing values)).
After the data entering the user shall be interrogate by the graphical interface (see figure 3; this form of graphical interface is obtained by pushing "Aerodynamic Coeff" button in the first form of graphical interface= figure 2) about the data dimensional parameters limits (maximum and minimum limit). According to these limits (not necessarily the minimum add maximum values entered in the data block), the calculation program shall operate the

necessary extrapolations. A twodimensional table “lista [3][33]” shall be supply to the data program (3 rows of 33 elements each with the following significance:

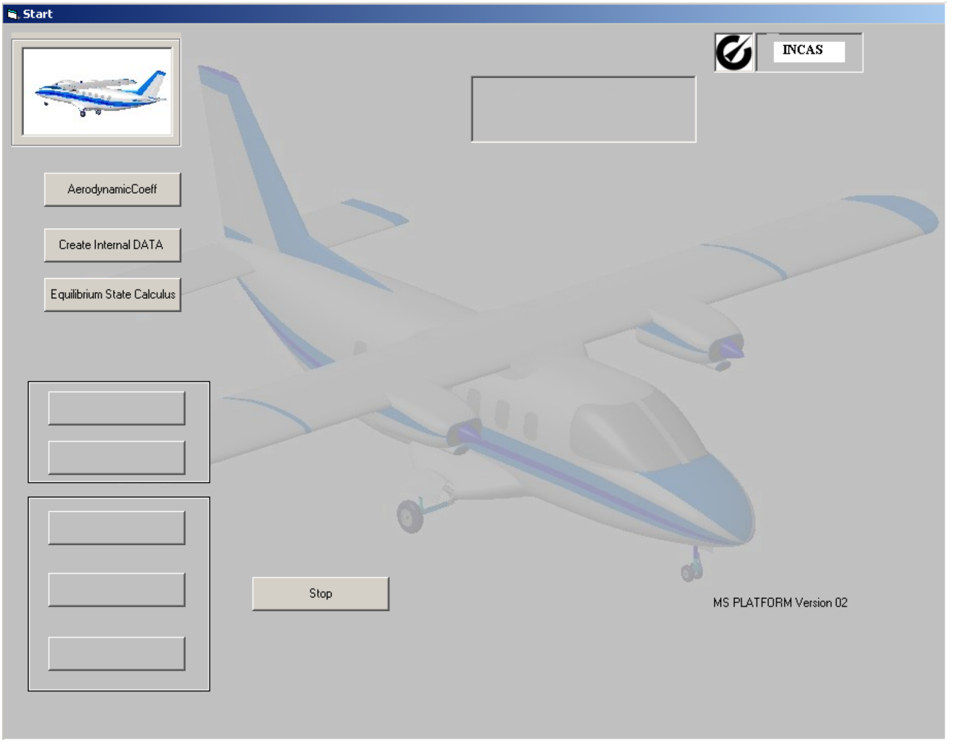

Fig.2

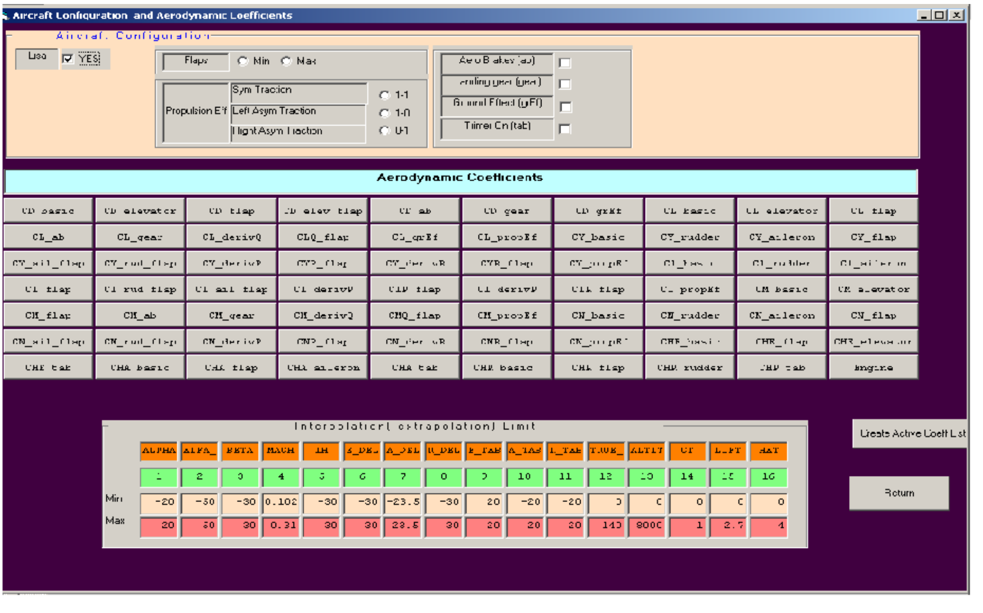

Fig. 3

lista [0][i] where i=1,32 represents a row of ZEROS (necessary for the calculation program to enter the interpolation values at each iteration); lista[1][i] where i=1,32 represents in order (which is given by the above enumeration of DIMENSIONS – starting with ALPHA,…) the MINIMUM limit values (if the parameter is an angle, it will be entered in degrees by user and automatically converted in radians for the calculus programme) of the dimensional parameters;

lista [2][i] where i=1,32 represents in order (which is given by the above enumeration of DIMENSIONS – starting with ALPHA,…) the MAXIMUM limit values (if the parameter is an angle, it will be entered in degrees by the user and automatically converted in radians for the calculus programme) of the dimensional parameters.

The graphical interface (see figure 3) shall allow the user to choose the aircraft configuration:

- **-clean (lisa) configuration**(with retracted flaps, airbrakes or landing gear);
- **-optional configuration**:
  - -flaps: intermediate (min) or max. position;
  - -extended airbrakes;
  - -extended landing gear;
  - -trimmer:
    - -elevator (the trimming control value is also chosen);
    - -aileron (the trimming control value is also chosen);
    - -rudder (the trimming control value is also chosen);

and the optional effects too (ground effect and propulsion effect):

- **-without optional effects;**
- **-optional effects:**
  - -ground effect
  - -propulsion effect:
    - -symmetrical thrust;
    - -left asymmetrical thrust;
    - -right asymmetrical thrust.

First time (see figure 3), the user must choice the “Aircraft Configuration” and then, in “Aerodynamic Coefficients”, he can check all coefficients including graphics with any parameter variation while the others are fixed (see figure 4). Here the user can create the active list of coefficients (push “Create Active Coeff”button) and return to the first form of graphical interface creating a new structure of data specific for software (push “Create Internal DATA”).

The graphical interface entry for the aircraft geometrical and inertial data and for the calculation options can be seen after pushing the “Equilibrium state calculus” button. The user can introduce or correct the values for geometrical and inertial data (push the “Set Physical Data” button to see the data if they are already charged).

7-Definition of the user’s calculus requirements – see figure 5 (explanations according to the format required by the calculation program: float table **option []**) :

NOTE 5: The following notations (of float type) are used: A= incidence angle(radians); T= thrust force (Newton); F=roll angle (positive for right inclination) (rad); CE=elevator deflection (positive for down deflection (rad); trim_CE= elevator trimmer deflection (rad); CA=aileron deflection (positive for right_hand_aileron downward and left_hand_aileron upward) (rad); trim_CA= aileron trimmer deflection (rad); CR=rudder deflection (positive for left_hand deflection (rad); trim_CR= rudder trimmer deflection (rad); H=altitude (m); V=speed (m/s); n= load factor; B= side-slip angle (rad); gamma=path angle (positive for climbing) (rad); Fc= controls force (N); xc=controls displacement (m).

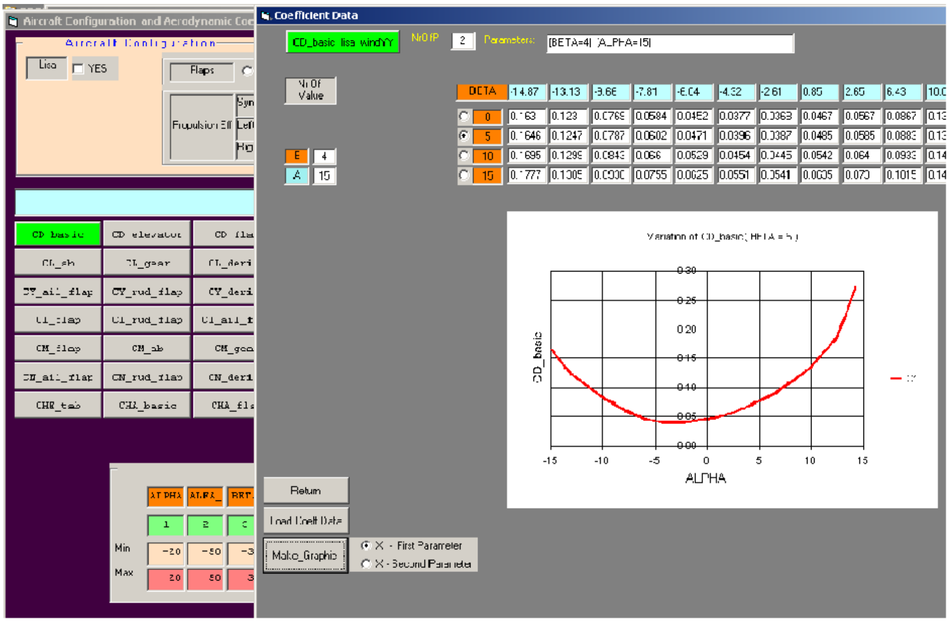

Fig.4

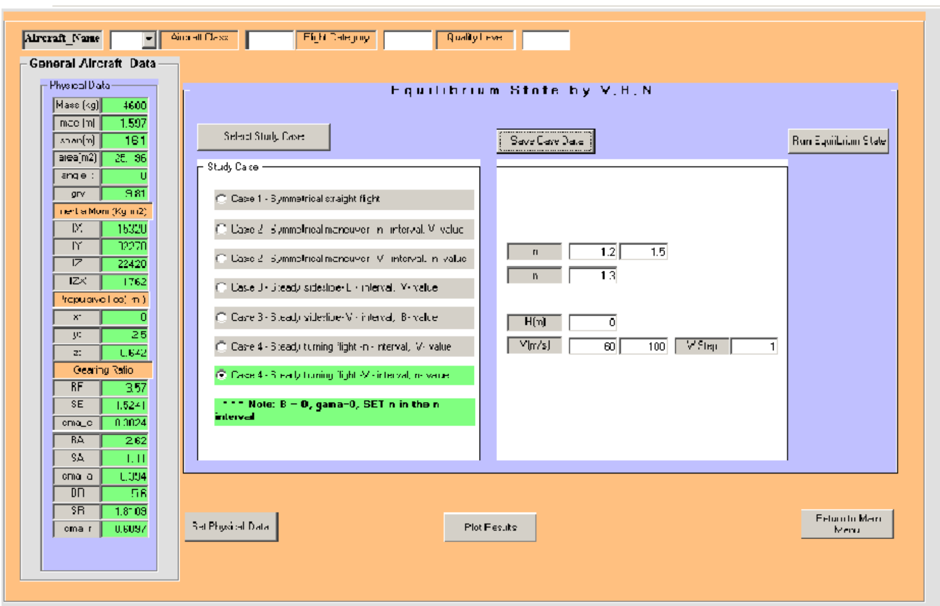

Fig.5

Fc and xc are float-type three –dimensional table data. By running the programme, informations about parameters and options here explained will appear on the screen, as results or inputs data.

NOTE 6: The user can chose the calculation parameters as punctual values or, for V, B, N, as repetitive calculation intervals. Each time a single parameter can be chosen as interval (**option[9]=0** indicates the choice of punctual values, without intervals, **option[9]=1** shows the choice of interval for V, **option[9]**=**2** indicates choice of interval for B, **option [9]=3** shows the choice of interval for n).

The values or intervals chosen by the user for V (implicitly M=V/(20.046346*sqrt(288-0.0065*H))) and B shall match the intervals defined by the user when entering the aerodynamic data.

Case 1= Non-accelerated symmetrical flight (**option[0]=1**):

-Imposed parameters: B=0, F=0, n=1, CA=0, CR=0, symmetrical thrust (**option[14]=0**);

-User's parameter selection: gamma (**option[1]),** H (**option[2]**), V(**option[3]** if a punctual value is chosen ; if a repetitive calculation interval is chosen **option[3]=**inferior-value, **option[4]=**superior_value), if an optional configuration is chosen **option[10]**=trim_CE, **option[15]=** ground effect (0= without ground effect, 1= with ground effect);

Case 2 = Overload Symmetrical flight (**option[0]=2**):

-Imposed parameters: B=0, F=0, CA=0, CR=0, symmetrical thrust (option[14]=0);

-Parameter selection: H (**option[2]**), V(**option[3]** if a punctual value is chosen; if a repetitive calculation interval is chosen **option[3]=**inferior-value, **option[4]=**superior_value), n (**option[5]** if a punctual value is chosen and if a repetitive calculation interval is chosen **option[5]=**inferior_value, **option [6]=**superior_value), if an optional configuration is chosen **option[10]**=trim_CE, **option[15]=** ground effect (0= without ground effect, 1= with ground effect);

Case 3 =Stationary Side-slip (**option[0]=3**) :

-Imposed parameters: n=1

-Parameter selection: gamma (**option[1]**), H (**option[2]**),V(**option[3]**) if a punctual value is chosen; if a repetitive calculation interval is chosen **option[3]=**inferior-value, **option[4]=**superior_value, B (**option[7]** if a punctual value is chosen; if a repetitive calculation interval is chosen **option[7]=**inferior-value, **option[8]=**superior_value), and if optional effects are chosen **option[13]**=propulsion_effect and correspondingly symmetrical or asymmetrical thrust (**option[14] =0** for functioning of both engines, **option[14]=1** for the left engine only functioning, **option[14]=2** for the right engine only functioning), if an optional configuration is chosen **option[10]**=trim_CE, **option[11]=**trim_CA, **option[12]=**trim_CR, **option[15]=** ground effect (0= without ground effect, 1= with ground effect);

Case 4 = Stationary coordinated turn (float **option[0]=4**) :

-Imposed parameters: B=0, gamma=0;

-Parameter selection: H (float **option[2]**),V(float **option[3]** if a punctual value is chosen; if a repetitive calculation interval is chosen **option[3]=**inferior-value, **option[4]=**superior_value), n (float option[5] if a punctual value is chosen; if a repetitive calculation interval is chosen **option[5] =** inferior-value, **option[6]=** superior_value), and if optional effects are chosen **option[13]** = propulsion_effect and correspondingly symmetrical or asymmetrical thrust (**option[14] =0** for functioning of both engines, **option[14]=1** for the left engine only functioning, **option[14]=2** for the right engine only functioning), if an optional configuration is chosen **option[10]**=trim_CE, option[11]=trim_CA, option[12]=trim_CR, **option[15]=** ground effect (0= without ground effect, 1= with ground effect);

The other information regarding the optional configuration [flaps (intermediate or maximum position), extended airbrakes, extended landing gear] are found implicitly in the calculation program by selecting information from the data base during the building process of the 70 element-structure needed by the “steady states calculus” program. Finally the user can plot results (see fig. 6–sample for speed interval calculus of controls forces in coordinated turn).

NOTE 7: For steady state calculus, a single control of engines is considered (the engine controls are coupled).

NOTE 8: In case when any parameter exceeds the limits imposed by the user (see lista[][]), the calculus programme provides the message: “For the …number coefficient the value of parameter … =… is out of defined domain for interpolation (extrapolation); if the parameter is an angle, the indicated value is in radians”.

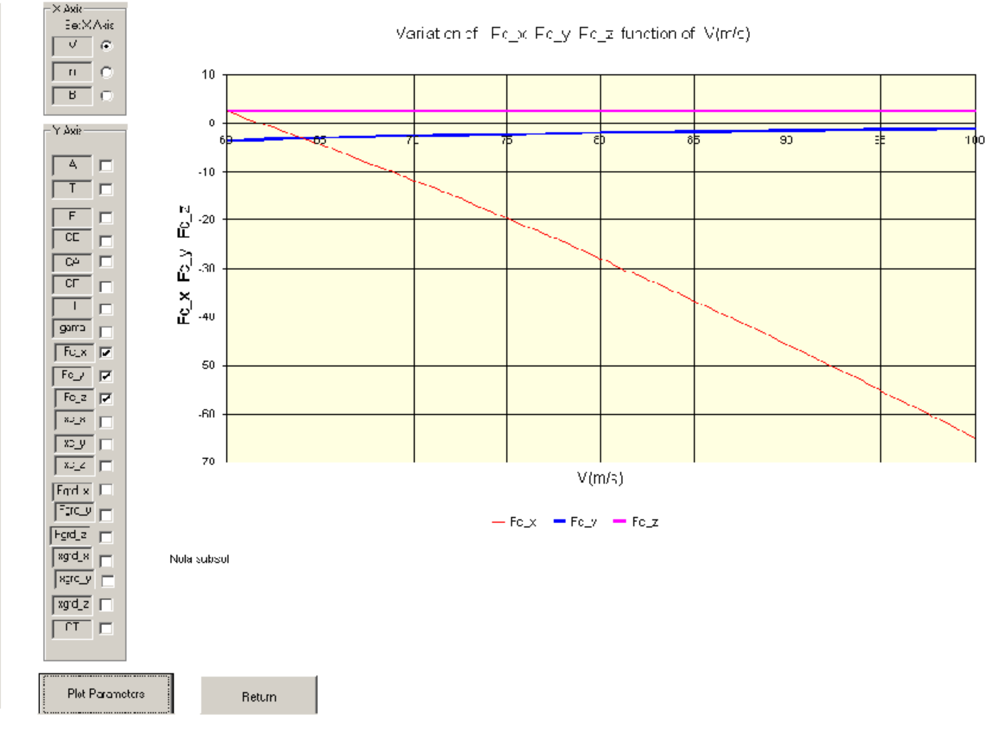

Fig.6

Conclusions

The way of data structuring up to four dimensions and achievement of interpolation (cubic spline type) or extrapolation (linear) leads to the program memory optimization (dynamic allocation) and to rapid calculation. The general data structure allows the user to choose the number of dimensions, dimensional parameters and parameter positioning. The user can chose from configuration, optional and equilibrium cases to punctual or extended values for speed, sideslip, load factor intervals, also having the possibility of graphic visualization of results (aero dynamic equilibrium parameters, forces and displacements at controls as well as their gradients).

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