PARAMETRIC ESTIMATION OF STABILITY AND FLIGHT CONTROL DERIVATIVES OF AT-26 "XAVANTE" AIRCRAFT USING NONLINEAR GLOBAL DYNAMIC MODEL

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Abstract. *One of the important characteristics associated with aircraft development and design is the estimation of stability and control derivatives. The flight estimated derivatives, throught parameter estimation techniques, are important to determine aerodynamic charateristics of brand new or yet not completely tested aircraft, being useful on the predicted parameters validation, flight simulator model upgrades, flying qualities evaluation, flight envelope expansion, flight control laws development and tuning and on accident investigation . In this work the parameter estimation of stability and control derivatives for the AT-26 4509 aircraft from Brazilian Air Force is developed through the application of output-error method with Levenberg-Marquardt optimization to real flight test data. The adopted modeling for the aircraft dynamics, called in this work as global, has six degree of freedom and uses nonlinear equations, comprising the set of state equations. As output equations, expressions that model the expected measurements on the sensors are presented. The sensors that measure the most relevant physical variables to the maneuvers are selected. Maneuvers are defined according to the applicable dynamic model needs and to the aircraft envelope are performed, providing the required data for the estimation program. After a iterative process of initial estimates tuning and of combination of dynamic models, the results for the global model are obtained, analyzed and compared against a reference estimation software, proving the adequacy of the overall presented estimation process.*

Keywords*: Output-error, Aircraft Parameter Estimation, Modeling and Simulation*

1. INTRODUCTION

The procedures for parameter estimation are well established: The dynamics of the aircraft is modeled by a set of differential equations and the external forces and moments acting on the vehicle are described through stability and control derivatives, which are considered unknowns.

By using specifically planned controls displacements, the test aircraft response and the mathematical model are obtained and compared. Appropriate parameter estimation algorithms are used to minimize the response error through iterative adjustments of model parameters (Raol et al, 2004).

Within the parameters estimation process, some criteria should be defined for error value. The optimization of the cost function obtained from the error will lead to a set of equations that, when solved, will result in the estimates of the dynamic system model parameters.

The "error" in this work is defined as the difference between the model to be estimated output and the measured output. In this case, the model input is the same input applied to the real system, being the method called "output error", as illustrated on Fig. 1.

The parameter estimation problem can be structured in four key elements: models, methods, maneuvers and measures. This approach was developed from the works of the DLR (German Aerospace Center) and is called "4-m" (Quad-M) (Jategaonkar and Plaetschke, 1989 e 1990).

In addition to the four "4-m" approach relevant factors, a last key element was included: validation. This element is very relevant as represents the closing of the parameter estimation process.

Therefore, this work considers the following key elements for the parameter estimation problem: models, methods, maneuvers, measurements and validation. This approach is called "4-m/v".

The aircraft dynamic model is generically described as follows:

$$\begin{cases} x(0) = x_0 \\ \dot{x}(t) = f\left[x(t), u(t), \Theta\right] \\ y(t) = h\left[x(t), u(t), \Theta\right] \end{cases} \tag{1}$$

As $x(t)$ being the continuous states vector, x_0 the known initial states, u(t) the controls inputs vector, y(t) the vector of estimated outputs (model response) and Θ the vector of parameters to be estimated. The symbols f e h represent generic real functions, linear or not.

The aircraft measurement model (observations) is generically described as follows (Raol et al, 2004):

$$z(k) = y(k) + v(k),\ k \in N\,. \tag{2}$$

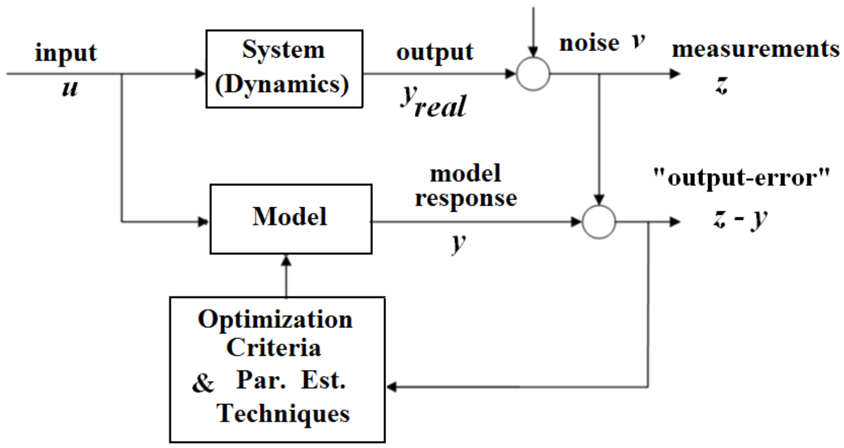


Figure 1. Output-error method

As *z(k)* being the measured outputs vector, *y(k)* the model response vector and *v(k)* measurement noise vector (assumed as white Gaussian noise with zero mean and *R* covariance), all in discrete time $k \in N$.

Among the developed techniques for parameter estimation, this work adopts the output-error approach with maximum likelihood function and Levenberg-Marquardt optimization. This technique was chosen because it is measurement noise tolerant, which is convenient for real flight test data, where there is a great possibility of existing noise.

Regarding maneuvers, it was chosen a specific sequence of control surface inputs that could lead to aircraft 3-axes excited movements, which is natural when using a global dynamic model.

As measurement means, the test aircraft was featured with a PCM (Pulse Code Modulation) data acquisition and recording system, having adequate variables number, measurement quality and acquisition rate for the test purposes.

For validation of the implemented <u>method</u> (one of the Quad-M key elements), it was chosen the ESTIMA software tool (Jategaonkar, 2001) as means to provide reference results (*benchmark*) for comparison. It was verified that the present development led to great part of the results being coherent with the reference program results, and that the differences could be adequately justified.

2. AIRCRAFT DYNAMIC MODELLING

In order to describe the details of the dynamic model, the following nomenclature will be utilized:

- V : true airspeed;
- α : angle of attack;
- β : sideslip angle;
- m : aircraft mass;
- b : wing span;
- $\bar{c}$: mean aerodynamic chord;
- I_x, I_y, I_z : moments of inertia on, respectively, *X*, *Y* and *Z* aircraft body axes;
- I_{xz} : product of inertia on *X* and *Z* aircraft body axes;
- $\bar{q}$: dynamic pressure;
- S : wing area;
- F_T : thrust;
- u : true airspeed component on *X* aircraft body axis;
- v : true airspeed component on *Y* aircraft body axis;
- w : true airspeed component on *Z* aircraft body axis;
- p : roll rate;
- q : pitch rate;
- r : yaw rate;
- ϕ : bank angle;
- θ : pitch angle; and

- ψ : heading angle.

The model uses all units according to SI (metric).

Although the most natural model for using real flight test data is that in which the states V , α and β are chosen, in the present work the option was to use the states u , v and w, which are the choice for the 6 degree-of-freedom (6DOF) ESTIMA tool dynamic model (Jategaonkar, 2001).

Therefore, the set of state equations addressed on this work is (Raol et al, 2004; Jategaonkar, 2001; Stevens and Lewis, 2003; Maine and Iliff, 1986):

$$\begin{cases}\dot{u} = r\,v - q\,w + \dfrac{\bar{q}\,S}{m}\,C_X + \dfrac{F_T}{m}\cos\alpha_T - g\;sen\,\theta \\ \dot{v} = p\,w - r\,u + \dfrac{\bar{q}\,S}{m}\,C_Y + g\;sen\,\phi\cos\theta \\ \dot{w} = q\,u - p\,v + \dfrac{\bar{q}\,S}{m}\,C_Z - \dfrac{F_T}{m}\,sen\,\alpha_T + g\cos\phi\cos\theta \\ \dot{p} = \dfrac{1}{I_x\,I_z - I_{xz}^2}\left\{I_{xz}\left[I_x - I_y + I_z\right]p\,q - \left[I_z\left(I_z - I_y\right) + I_{xz}^2\right]q\,r + I_z\,\bar{q}\,S\,b\,C_l + I_{xz}\,\bar{q}\,S\,b\,C_n\right\} \\ \dot{q} = \dfrac{1}{I_y}\left\{\left(I_z - I_x\right)p\,r - I_{xz}\left(p^2 - r^2\right) + \bar{q}\,S\,\bar{c}\,C_m + F_T\left(x_T\,sen\,\sigma_T + z_T\cos\sigma_T\right)\right\} \\ \dot{r} = \dfrac{1}{I_x\,I_z - I_{xz}^2}\left\{\left[I_x\left(I_x - I_y\right) + I_{xz}^2\right]p\,q - I_{xz}\left[I_x - I_y + I_z\right]q\,r + I_{xz}\,l + I_x\,n\right\} \\ \dot{\phi} = p + q\,sen\phi\tan\theta + r\cos\phi\tan\theta \\ \dot{\theta} = q\cos\phi - r\;sen\,\phi \\ \dot{\psi} = \left(q\;sen\,\phi + r\cos\phi\right)\sec\theta \\ \dot{h} = u\;sen\,\theta - v\cos\theta\;sen\,\phi - w\cos\theta\cos\phi\end{cases} \tag{3}$$

As C_X , C_Y and C_Z being the non-dimensional coefficients of aerodynamic forces on *X*, *Y* and *Z* axes, respectively. The C_l , C_m and C_n values are non-dimensional coefficients of aerodynamic moments on *X*, *Y* and *Z* axes, respectively.

The values C_X and C_Y comply with the following expressions:

$$\begin{cases}C_X = -C_D\cos\alpha + C_L\;sen\,\alpha \\ C_Z = -C_D\;sen\,\alpha - C_L\cos\alpha\end{cases} \tag{4}$$

As C_D and C_L being the non-dimensional coefficients of drag force (*D*) and lift force (*L*), respectively.

The aerodynamic force coefficients are expressed as follows (linearized):

$$\begin{cases}C_L = C_{L_b} + C_{L_\alpha}\,\alpha + C_{L_q}\,\dfrac{q\,\bar{c}}{V} + C_{L_{\delta m}}\,\delta_m + C_{L_{\dot{\alpha}}}\,\dfrac{\dot{\alpha}\,\bar{c}}{V}, \quad C_D = C_{D_b} + \dfrac{1}{\pi\,e\,\Lambda}\,C_L^2 \\ C_Y = C_{Y_b} + C_{Y_\beta}\,\beta + C_{Y_p}\,\dfrac{p\,b}{V} + C_{Y_r}\,\dfrac{r\,b}{V} + C_{Y_{\delta l}}\,\delta_l + C_{Y_{\delta n}}\,\delta_n\end{cases} \tag{5}$$

As "e" being the Oswald efficiency factor and Λ the aspect ratio. The δ_l , δ_m and δ_n values represent the angular control surface displacements.

The term C_{L_b} , as well as the other terms with subscript "*b*" in this work, represent the measured values biases. C_{L_α} represents the non-dimensional partial derivative of the lift force *L* related to angle of attack α . Similar definitions are applicable to other non-dimensional force and moments coefficients.

The aerodynamic moments coefficients are expressed as follows (linearized):

$$\begin{cases}C_l = C_{l_b} + C_{l_\beta}\,\beta + C_{l_p}\,\dfrac{p\,b}{V} + C_{l_r}\,\dfrac{r\,b}{V} + C_{l_{\delta l}}\,\delta_l + C_{l_{\delta n}}\,\delta_n \\ C_m = C_{m_b} + C_{m_\alpha}\,\alpha + C_{m_q}\,\dfrac{q\,\bar{c}}{V} + C_{m_{\delta m}}\,\delta_m + C_{m_{\dot{\alpha}}}\,\dfrac{\dot{\alpha}\,\bar{c}}{V} \\ C_n = C_{n_b} + C_{n_\beta}\,\beta + C_{n_{\dot{\beta}}}\,\dfrac{\dot{\beta}\,b}{V} + C_{n_p}\,\dfrac{p\,b}{V} + C_{n_r}\,\dfrac{r\,b}{V} + C_{n_{\delta l}}\,\delta_l + C_{n_{\delta n}}\,\delta_n\end{cases} \tag{6}$$

The output equations are:

$$\begin{cases} V_y = \sqrt{u^2 + v^2 + w^2} \\ \alpha_y = K_\alpha \tan^{-1}\left(\dfrac{w}{u}\right) + \alpha_b \,,\; \beta_y = K_\beta \, sen^{-1}\left(\dfrac{v}{\sqrt{u^2+v^2+w^2}}\right) + \beta_b \\ p_y = p + p_b \,, q_y = q + q_b \,, r_y = r + r_b \\ \phi_y = \phi + \phi_b \,, \theta_y = \theta + \theta_b \,, \psi_y = \psi + \psi_b \\ a_{X_y} = a_X^{CG} - x_{nx}\left(q^2 + r^2\right) + y_{nx}\left(p\,q - \dot r\right) + z_{nx}\left(p\,r + \dot q\right) + a_{X_b},\, a_X^{CG} = \dfrac{1}{m}\left(\bar q\, S\, C_X + X_T\right) \\ a_{Y_y} = a_Y^{CG} + x_{ny}\left(p\,q + \dot r\right) - y_{ny}\left(r^2 + p^2\right) + z_{ny}\left(q\,r - \dot p\right) + a_{Y_b},\, a_Y^{CG} = \dfrac{1}{m}\bar q\, S\, C_Y \\ a_{Z_y} = a_Z^{CG} + x_{nz}\left(p\,r - \dot q\right) + y_{nz}\left(q\,r + \dot p\right) - z_{nz}\left(p^2 + q^2\right) + a_{Z_b},\, a_Z^{CG} = \dfrac{1}{m}\left(\bar q\, S\, C_Z + Z_T\right) \\ h_y = h,\; \dot p_y = \dot p\,,\; \dot q_y = \dot q,\; \dot r_y = \dot r \end{cases} \tag{7}$$

The complete set of parameters Θ resulting from the previous model is:

$$\Theta = [\, C_{L_b}\; C_{L_\alpha}\; C_{L_q}\; C_{L_{\delta m}}\; C_{L_{\dot\alpha}}\; C_{D_b}\; e(*)\; C_{Y_b}\; C_{Y_\beta}\; C_{Y_p}\; C_{Y_r}\; C_{Y_{\delta l}}\; C_{Y_{\delta n}}\; C_{l_b}\; C_{l_\beta}\; C_{l_p}\; C_{l_r}\; C_{l_{\delta l}}\; C_{l_{dn}} \ldots$$
$$\cdots C_{m_b}\; C_{m_\alpha}\; C_{m_q}\; C_{m_{\delta m}}\; C_{m_{\dot\alpha}}\; C_{n_b}\; C_{n_\beta}\; C_{n_{\dot\beta}}\; C_{n_p}\; C_{n_r}\; C_{n_{\delta l}}\; C_{n_{\delta n}}\; u_o\; v_o\; w_o\; p_o\; q_o\; r_o\; \phi_o\; \theta_o\; \psi_o\; h_o \ldots.$$
$$\cdots r_b\; q_b\; p_b\; K_\alpha\; \alpha_b\; K_\beta\; \beta_b\; p_b\; q_b\; r_b\; \phi_b\; \theta_b\; \psi_b\; a_{x_b}\; a_{y_b}\; a_{z_b}\,] \tag{8}$$

(*) The "e" parameter means the Oswald efficiency factor.

3. METHOD AND MENEUVERS FOR PARAMETER ESTIMATION

3.1. Methodology

The methodology for parameter estimation comprises, basically, the algorithm that adjusts the parameter values used by the mathematical model until the calculated response curves match the real data curves in a satisfactory way.

In mathematics terms, it starts from Eq. (2):

$z(k) = y(k) + v(k),\; k \in N$

The objective of the method is to minimize the cost function based on the maximum likelihood function, which, in the present work, has the following structure:

$$p\,(z\,|\,\Theta\,, R) = \left[(2\,\pi)^{m_Y}|R|\right]^{-N/2} \exp\left\{-\frac{1}{2}\sum_{k=1}^{N}\left[z(k) - y(k)\right]^T\left[R^{-1}\right]\left[z(k) - y(k)\right]\right\} \tag{9}$$

Where R is the covariance of the noise $v(k)$, m_Y is the number of measured variables and N is the number of samples.

The cost function is given by the following expression:

$$J\,(\Theta) = -\log\, p\,(z\,|\,\Theta\,, R\,) = \frac{1}{2}\sum_{k=1}^{N}\left[z(k) - y(k)\right]^T\left[R^{-1}\right]\left[z(k) - y(k)\right] + \frac{N}{2}\ln|R| + const. \tag{10}$$

As

$$[R] = \frac{1}{N}\sum_{k=1}^{N}\left[z(k) - y(k)\right]\left[z(k) - y(k)\right]^T \tag{11}$$

When R is used on Eq. (10), the first term becomes constant and equal to $m_Y \dfrac{N}{2}$ and the cost goes to:

$J\,(\Theta) = |\,R\,|$, where $|\,R\,|$ represents the determinant of R.

The chosen optimization algorithm was the Levenberg-Marquardt method, which is based on the Newton-Raphson method:

$$\left[\Theta_{i+1}\right] = \left[\Theta_i\right] - \left[\nabla^2_\Theta\, J(\Theta_i)\right]^{-1}\left[\nabla^T_\Theta\left(\Theta_i\right)\right] \tag{12}$$

As Θ_i being the parameters values during the iteration i.

In this expression, the values of the gradient elements are (Raol et al, 2004):

$$\left[\nabla_\Theta J(\Theta)_j\right] = \left[\frac{\partial J(\Theta)}{\partial \Theta_j}\right] = -\sum_{k=1}^{N}\left[z(k) - y(k)\right]^T \left[R^{-1}\right]\left[\frac{\partial y}{\partial \Theta_j}(k)\right] \tag{13}$$

$$\left[\nabla^2_\Theta J(\Theta)_{j\,m}\right] = \left[\frac{\partial^2 J(\Theta)}{\partial \Theta_j \, \partial \Theta_m}\right] \cong \sum_{k=1}^{N}\left[\frac{\partial y}{\partial \Theta_j}(k)\right]^T \left[R^{-1}\right]\left[\frac{\partial y}{\partial \Theta_m}(k)\right] \tag{14}$$

With j and m varying from 1 to m_Y (Gauss-Newton method).

The Levenberg-Marquardt method adds a $\lambda\, I$ term to the Gauss-Newton expression:

$$\left[\nabla^2_\Theta J(\Theta)_{j\,m}\right] = \left[\frac{\partial^2 J(\Theta)}{\partial \Theta_j \, \partial \Theta_m}\right] \cong \sum_{k=1}^{N}\left[\frac{\partial y}{\partial \Theta_j}(k)\right]^T \left[R^{-1}\right]\left[\frac{\partial y}{\partial \Theta_m}(k)\right] + \left[\lambda\, I_{jm}\right] \tag{15}$$

Where λ is a scalar value and I_{jm} is the "*jm*" element of the identity matrix.

The Levenberg-Marquardt technique solves the problem of an ill-conditioned Hessian matrix $\nabla^2_\Theta J(\Theta)$ and is used on this work.

The optimized process comprises a parameter iterative evolution based on Eq. (12) and should be arrested according to a stopping criteria.

In the present work, the following stopping criteria are defined:

- maximum of 100 iterations; and/or
- cost function variation below 0.1%.

3.2. Maneuvers

The choice of exciting maneuvers for the chosen aircraft dynamic is a fundamental aspect of the parameter estimation process. Depending on the kind of utilized model, the control surface that excites the movement will be different. The way the control surfaces are displaced is also an important factor, once the obtainance of the desired dynamic is linked to de excited maneuver.

For the present work, where it is utilized a global model, it was searched maneuvers that could excite the three aircraft body axes in a same maneuver. Among the conventional maneuvers, it was not verified a single one that could individually present the requested scope, what resulted on the need to search an alternate maneuver profile to fit the global model needs.

Based on the problem's needs, it was chosen an exciting sequence according to Fig. 2 below:

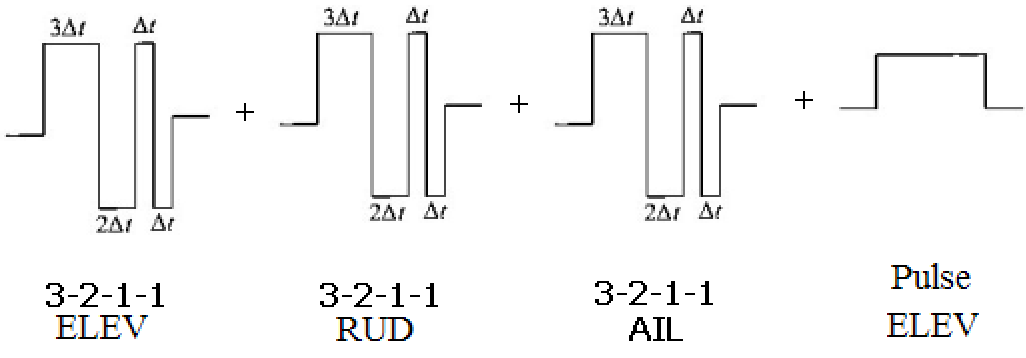


Figure 2. Maneuver profile for global estimation

The value of Δt, time frame for full displacement of the applicable control surfaces, should be adjusted on the 3-2-1-1 maneuvers in order to adequately excite the desired maneuvers. This adjustment was done in flight, just before the execution of the maneuvers. The time frame for the pulse displacement was around 10 seconds.

Additionally, it was also utilized frequency sweep type excitements, for elevator, rudder and aileron, as illustrated on Fig. 3. Such inputs can improve the control parameters estimation (which involve δ_l, δ_m e δ_n).

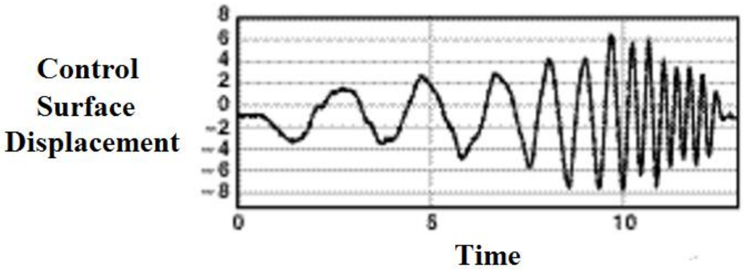


Figure 3. Frequency sweep type excitement

4. EXPERIMENTAL RESULTS AND METHOD VALIDATION

4.1. Case studies

The parameter estimation software developed to implement the present estimation process (OEGlobal.m) should start from initial parameter estimates, to, then, iteratively proceed the optimization process.

Once the choice of the initial parameter estimates resulted in a complex task, where small differences on those values led to large variations on the state and observations curves, it was decided to develop a parameter "pre-estimation process".

Such process involved case studies that could solve the problem in three distinct steps:

Case Study 1 – Verification of adequate functioning of the optimization algorithm.

Case Study 2 – Longitudinal movement parameters pre-estimation.

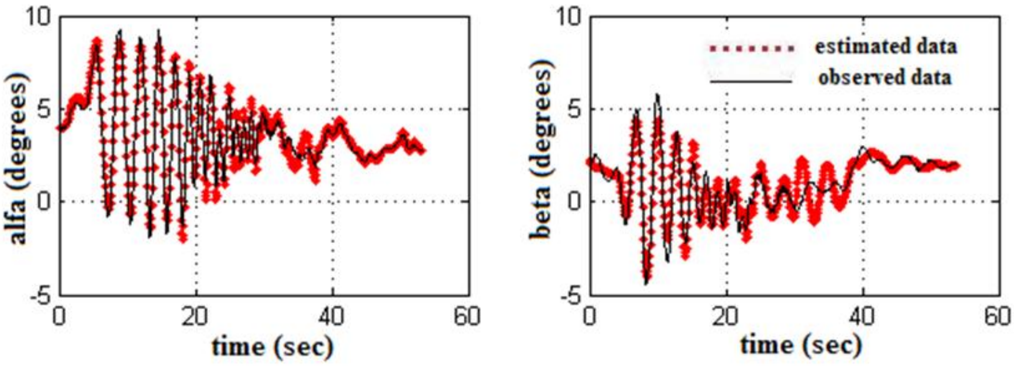
Case Study 3 – Lateral-directional movement parameters pre-estimation.

On case study 1 it was applied a linear longitudinal dynamic model, when it was confirmed that the part of the software associated to the optimization was adequate. As initial parameter conditions, it was chosen values for a similar aircraft (SIAI-Marchetti S-211)(Roskam, 1995).

On case studies 2 and 3, the global model was "separated" into longitudinal and lateral-directional parts, being the coupling states considered as "inputs" by using instrumentation data as the source.

The same way as on the case study 1, the definition of the parameters initial conditions on case studies 2 and 3 was based on the referred similar aircraft, which were refined through successive estimations until to obtain the estimation of all test points available for each case.

Figure 4 shows the results for case studies 2 and 3:



Long. Mod.: Elev. Freq. Sw. L-D Mod.: Rud. Freq. Sw.

Figure 4. Results for frequency sweep type excitement

4.2. Results

The pre-estimated parameters as per case studies 2 and 3 were combined in order to obtain a complete set of initial parameter estimates for the global model.

After the estimation process, which involved the choice of compatible values of λ, it was obtained the following graphic results, illustrated on Fig. 5 (example for test point at speed/Mach= 135 KIAS/0,37, 30000 ft, 3700 kgf and 27.8% $\bar{c}$), by using the "OEGlobal" tool:

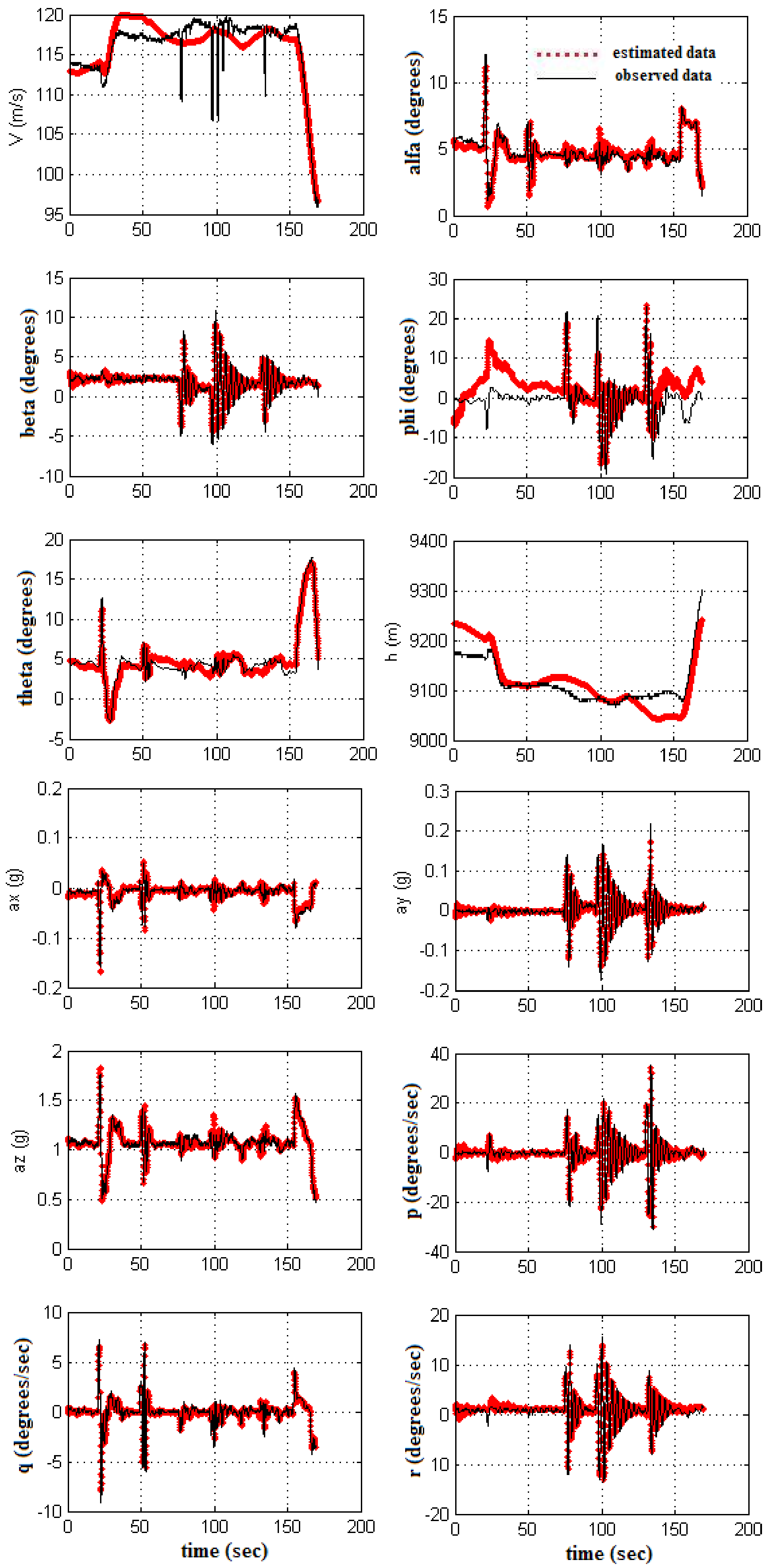


Figure 5. Graphic results for global estimation

When comparing the graphic results for the "OEGlobal" parameter estimation tool with real flight test data, it can be verified that the model was able to reproduce the complete maneuvers in a satisfactory way. Some variables (V , θ and h), however, presented relevant differences, which can be justified by the convergence to some local minimum instead of the global one.

4.3. Method Validation

The method validation (one of the Quad-M key elements) was based on the comparison with the ESTIMA tool results for the same test point, as registered on Tab. 1 as follows:

Table 1. Comparison between ESTIMA and "OEGlobal" results

Parameter	ESTIMA tool	OEGlobal tool	Parameter	ESTIMA tool	OEGlobal Tool
C_{L_b}	0.123	0.1169	C_{l_r}	-0.046 (**)	-0.1524
C_{L_α}	7.96	6.0344	$C_{l_{\delta l}}$	0.261	0.2254
C_{L_q}	-20.6	-29.052	$C_{l_{\delta n}}$	0.027 (**)	0.0080
$C_{L_{\delta m}}$	1.269 (**)	0.0660	C_{n_b}	0.003 (**)	0.0015
C_{D_b}	0.0776	0.0254	C_{n_β}	0.068	0.0761
e	0.8 (*)	0.8000	C_{n_p}	-0.0147 (**)	-0.3194
C_{m_b}	0.024	0.0368	C_{n_r}	-0.098	-0.1468
C_{m_α}	-0.279	-0.4925	$C_{n_{\delta l}}$	-0.029 (**)	-0.0077
C_{m_q}	-0.858 (**)	-4.3890	$C_{n_{\delta n}}$	-0.076	-0.0887
$C_{m_{\delta m}}$	-0.401	-0.6304	α_b	0 (*)	-0.0181
C_{Y_b}	-0.014	-0.0096	β_b	0.052	0.0361
C_{Y_β}	-0.494	-0.3180	p_b	-0.004	-0.0062
C_{Yp}	0.54	0.5115	q_b	0 (*)	0.0007
C_{Yr}	0.037 (**)	0.3603	r_b	0.011	0.0232
$C_{Y_{\delta l}}$	-0.192 (**)	-0.2702	ϕ_b	-0.0303	0.0963
$C_{Y_{\delta n}}$	0.164	0.1771	θ_b	0 (*)	0.0027
C_{l_b}	- 0.002 (**)	0.0006	K_α	1 (*)	1.3114
C_{l_β}	-0.132	-0.1059	K_β	0.853	0.8179
C_{l_p}	-0.395	-0.3356	a_{X_b}	0 (*)	-0.6333
Iter	70	31	a_{Y_b}	0 (*)	0.0961
Final Cost	2.31 e-10	1.07e-40	a_{Z_b}	0 (*)	-0.6557

Some parameters on Tab.1 (**) present relevant differences when compared to ESTIMA results, which can be attributed to some differences between the real test conditions and the data inserted on the referred tool during the estimation exercise, such as sensor positioning, cg position and initial conditions, which where slightly different. Besides, some parameters were considered constant (*) during the ESTIMA estimation exercise for convenience. Additionally, there is a possibility of reaching different cost minima.

It can be verified, then, that the tool developed on the present work presented great part of the results aligned with the reference software.

The numeric results that were considerably different (**) can be considered a small part and can be explained.

Therefore, the method addressed on this work for parameters estimation was considered valid under the comparison with the reference program aspect.

5. CONCLUSIONS

In order to find a direct application for the global model to aircraft three body axes maneuvers, it was followed a systematic approach that started by the verification of the optimization algorithm proper working, going on the initial parameters pre-estimation through the use of "separated" dynamic models and was concluded with a combination of these initial parameter pre-estimates in order to reach global model adequate convergence.

The process implementation involved the use of models, methods, maneuvers and measurement based on the "4-m/v" approach.

The choice of global dynamic model was based on the ESTIMA parameter estimation software tool, which was the reference for validation, what partially comprised the "v" element on the "4m/v" approach (only the method validation).

From the comparison against the ESTIMA tool results, it could be verified that the "OEGlobal" parameter estimation tool was equivalent, once great part of its results were coherent with the reference program, being the significant differences justifiable.

6. AKNOWLEDGEMENTS

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7. REFERENCES

Jategaonkar, R. V. and Plaetschke, E., 1989, "Algorithms for Aircraft Parameter Estimation Accounting for Process and Measurement Noise." Journal of Aircraft, Vol. 26, No. 4, pp. 360-372.

Jategaonkar, R. V. and Plaetschke, E., 1990, "Identification of Moderately Nonlinear Flight Mechanics System with Additive Process and Measurement Noise", Journal of Guidance, Control and Dynamics, Vol. 13, No. 2, pp. 277-285.

Jategaonkar, R. V., 2001, "ESTIMA: A Modular and Integrated Software Tool for Parameter Estimation and Simulation of Dynamic Systems – User´s Manual, Version 1.0", DLR, Braunshweig, Germany.

Maine, R.E. and Iliff, K. W., 1986, "Application of Parameter Estimation to Aircraft Stability and Control: The Output Error Approach", RP 1168, NASA, Edwards, Calif., USA.

Raol, J. R.; Girija, G.; Singh, J. , 2004, "Modelling and Parameter Estimation of Dynamic Systems". The Institution of Electrical Engineers, London, 388 p.

Roskam, J. , 1995, "Airplane flight dynamics and automatic flight controls. Part I", DARcorporation , Lawrence, KS, USA, 576 p.

Stevens, B. L. and Lewis, F. L., 2003, "Aircraft Control and Simulation", 2nd. ed., John Wiley & Sons , Hoboken, NJ, USA, 664 p.

8. RESPONSIBILITY NOTICE

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