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Lateral Parameter Estimation of Aircraft with Different Initial Conditions

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ABSTRACT: This paper aims to estimate the lateral aerodynamic parameters of the aircraft from the available measurements with different initial conditions. In this current work Filter Error Method (FEM) which accounts for both process and measurement noise, is used to estimate the lateral aerodynamic parameters from aircraft data. FEM algorithm is developed in MATLAB environment. With the developed algorithm studies are carried out at different instance of the aircraft and the estimated parameters are compared with wind tunnel predictions.

KEYWORDS: Aerodynamic parameter, Filter Error Method, Gauss Newton Method, Kalman Filter.

I.INTRODUCTION

Parameter estimation, is the subfield of system identification, which determines the best estimates of the parameters occurring in the model. Aircraft parameter estimation is the best example of system identification. An aircraft motion is described by equations of motion derived from the Newtonian mechanics, considering the vehicle as a rigid body. The aerodynamic forces and moments cannot be measured directly. However, aerodynamic modeling followed by parameter estimation helps to determine the aerodynamic parameters. Conventional methods of parameter estimation are (i)Equation Error Method[2] (ii) Output Error Methods (OEM)[3,4] and (iii) Filter Error Methods (FEM). Out of these methods Filter Error Method (FEM), is the most general stochastic approach for aircraft parameter estimation, which accounts for both process and measurement noise. In this current work Filter Error Method (FEM), is used to estimate the lateral aerodynamic parameters. FEM algorithm is developed in MATLAB environment. State estimation is carried out with Kalman Filter and the parameters are updated using Gauss Newton Method. With the developed algorithm studies are carried out at different instance of the aircraft and the estimated parameters are compared with wind tunnel predictions.

II. LATERAL DYNAMICS

Aircraft experiences aerodynamic forces and moments during their motion in atmosphere.

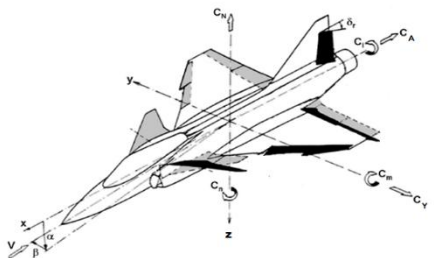

Fig. 1. Aerodynamic forces and moments

Fig.1 shows the different forces and moments acting on the aircraft along the three axis. Aerodynamic force acting on the aircraft with respect to lateral plane are given from (1). [1]

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$$F_y = C_Y \bar{q} S \qquad (1)$$

Aerodynamic moments are given by (2)-(3)

$$L = C_l \bar{q} S b \qquad (2)$$

$$N = C_n \bar{q} S b \qquad (3)$$

Where $\bar{q}$ is the dynamic pressure, S is the reference area, b is the lateral reference length, C_Y, C_l, C_n are the total side force coefficient, total rolling moment coefficient, and yawing moment coefficients.. The state equations are given from (4)-(8).

$$\dot{\beta} = \frac{(u^2+w^2)\dot{v} - v(u\dot{u} + w\dot{w})}{(u^2+v^2+w^2)\sqrt{u^2+w^2}} \qquad (4)$$

$$\dot{\psi} = q\sin\phi + r\cos\phi \qquad (5)$$

$$\dot{\phi} = p - \frac{\sin\psi}{\cos\psi}(q\cos\phi - r\sin\phi) \qquad (6)$$

$$\dot{p} = \frac{C_l\bar{q}Sb + I_{yz}(q^2-r^2) + rq(I_{yy}-I_{zz}) + I_{xy}(\dot{q}-pr) + I_{xz}(\dot{r}+pq)}{I_{xx}} \qquad (7)$$

$$\dot{r} = \frac{C_n\bar{q}Sb + I_{yx}(p^2-q^2) + pq(I_{xx}-I_{yy}) + I_{zx}(\dot{p}-qr) + I_{yz}(\dot{q}+rp)}{I_{yy}} \qquad (8)$$

Where u, v, w are the translational velocity, p, q, r are the body rates, V is the vehicle velocity, , β is the side slip angle, I_{xx}, I_{yy}, I_{zz} are the moment of inertia and I_{xy}, I_{yz}, I_{zx} are the product of inertia, ϕ, ψ are the euler angles. The aerodynamic coefficients are modelled in linear form as:

$$C_Y = C_{Y0} + C_{Y\beta}\beta + C_{Y\delta e1}\delta_{e1} + C_{Y\delta e2}\delta_{e2} + C_{Y\delta r1}\delta_{r1} + C_{Y\delta r2}\delta_{r2} \qquad (9)$$

$$C_l = C_{l0} + C_{l\beta}\beta + C_{l\delta e1}\delta_{e1} + C_{l\delta e2}\delta_{e2} + C_{l\delta r1}\delta_{r1} + C_{l\delta r2}\delta_{r2} \qquad (10)$$

$$C_n = C_{n0} + C_{n\beta}\beta + C_{n\delta e1}\delta_{e1} + C_{n\delta e2}\delta_{e2} + C_{n\delta r1}\delta_{r1} + C_{n\delta r2}\delta_{r2} \qquad (11)$$

where $C_{Y0,} C_{l0,} C_{n0,} C_{Y\beta}, C_{l\beta}, C_{n\beta}$ are the basic coefficients and

$C_{Y\delta e1}, C_{Y\delta e2}, C_{Y\delta r1}, C_{Y\delta r2}, C_{l\delta e1}, C_{l\delta e2}, C_{l\delta r1}, C_{l\delta r2}, C_{n\delta e1}, C_{n\delta e2}, C_{n\delta r1}, C_{n\delta r2}$ are the incremental coefficients due to control surface deflections. Thus the unknown parameters to be estimated are given as:

$$\theta^T = [C_{Y0}C_{Y\beta}C_{Y\delta e1}C_{Y\delta e2}C_{Y\delta r1}C_{Y\delta r2}C_{l0}C_{l\beta}C_{l\delta e1}C_{l\delta e2}C_{l\delta r1}C_{l\delta r2}C_{n0}C_{n\beta}C_{n\delta e1}C_{n\delta e2}C_{n\delta r1}C_{n\delta r2}] \qquad (12)$$

Observation equations are given by (13)-(20)

$$\beta_m = \beta \qquad (13)$$

$$\psi_m = \psi \qquad (14)$$

$$\phi_m = \phi \qquad (15)$$

$$p_m = p \qquad (16)$$

$$r_m = r \qquad (17)$$

$$\dot{p}_m = \frac{C_l\bar{q}Sb + I_{yz}(q^2-r^2) + rq(I_{yy}-I_{zz}) + I_{xy}(\dot{q}-pr) + I_{xz}(\dot{r}+pq)}{I_{xx}} \qquad (18)$$

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$$\dot{r}_m = \frac{C_n \bar{q} S b + I_{yx}(p^2 - q^2) + pq(I_{xx} - I_{yy}) + I_{zx}(\dot{p} - qr) + I_{yz}(\dot{q} + rp)}{I_{yy}} \quad (19)$$

$$a_{ym} = \frac{C_Y \bar{q} S}{m} \quad (20)$$

Where, m is the mass of the vehicle, $\beta_m, \psi_m, \phi_m, p_m, r_m$ are the sideslip angle, euler angles, and body rates, $\dot{p}_m, \dot{r}_m$ are the measured angular accelerations and a_{ym} are the measured acceleration.

III. EFFECT OF INITIAL CONDITION

The effect of initial condition of the coefficient on the estimates is studied by considering different initial conditions. The different initial conditions are shown in table 1.

Table 1: Different initial conditions

Parameters	Initial values (case 1)	Initial values (case 2)	Initial values (case 3)
C_{Ye1} /degree	0.0112	0.0115	-0.0109
C_{Ye2} /degree	0.0112	0.0115	-0.0109
C_{Yr1} /degree	-0.0203	-0.0286	-0.0229
C_{Yr2} /degree	-0.0203	-0.0286	-0.0229

The presence of process noise makes Equation Error Method ,Output Error Method estimation techniques less efficient. Therefore, Filter Error Method [5] is used in this work which account for process and measurement noise. Since the system is stochastic in nature a steady state Kalman filter is used for obtaining the true state variables from the noisy measurements.

IV. RESULTS AND DISCUSSION

Estimation is carried out for a period of 10s with 500 samples. Region considered for the estimation process is for the vehicle time 320-330s. The initial values of the estimates are taken from the wind tunnel data. The variation of angle of attack, dynamic pressure, Mach number, relative velocity and control surface deflections during this region are shown in Fig.2 and 3. The estimated lateral aerodynamic coefficients are shown in Fig 4,5 and 6.

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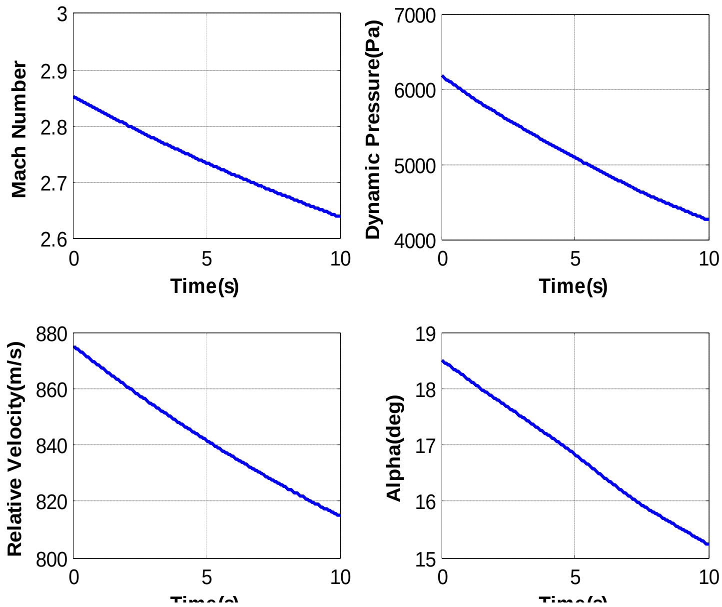

Fig. 2. Mach number, relative velocity, dynamic pressure and alpha during the estimation region.

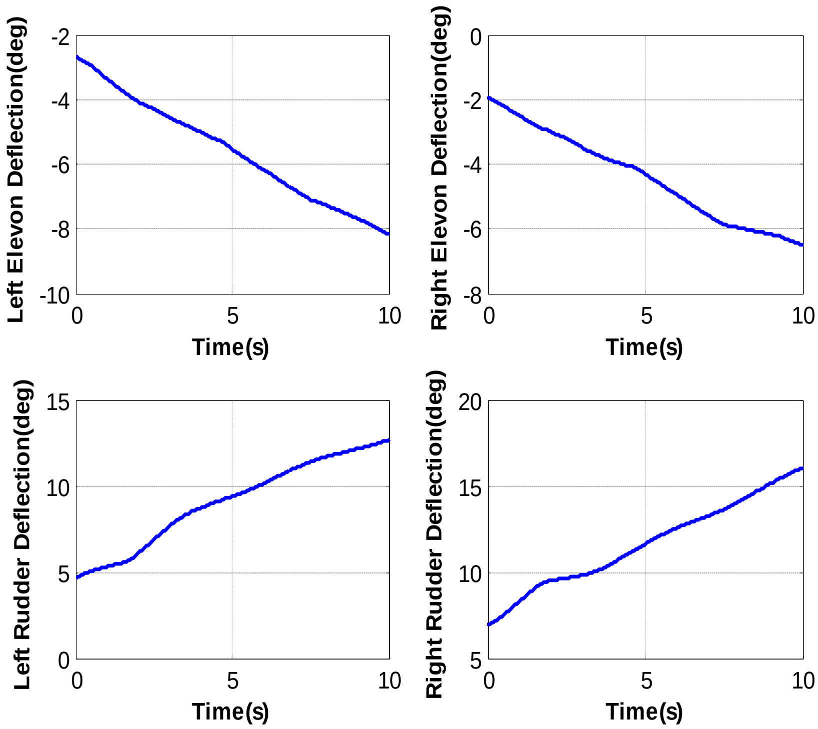

Fig.3.Control surface deflections during the estimation region

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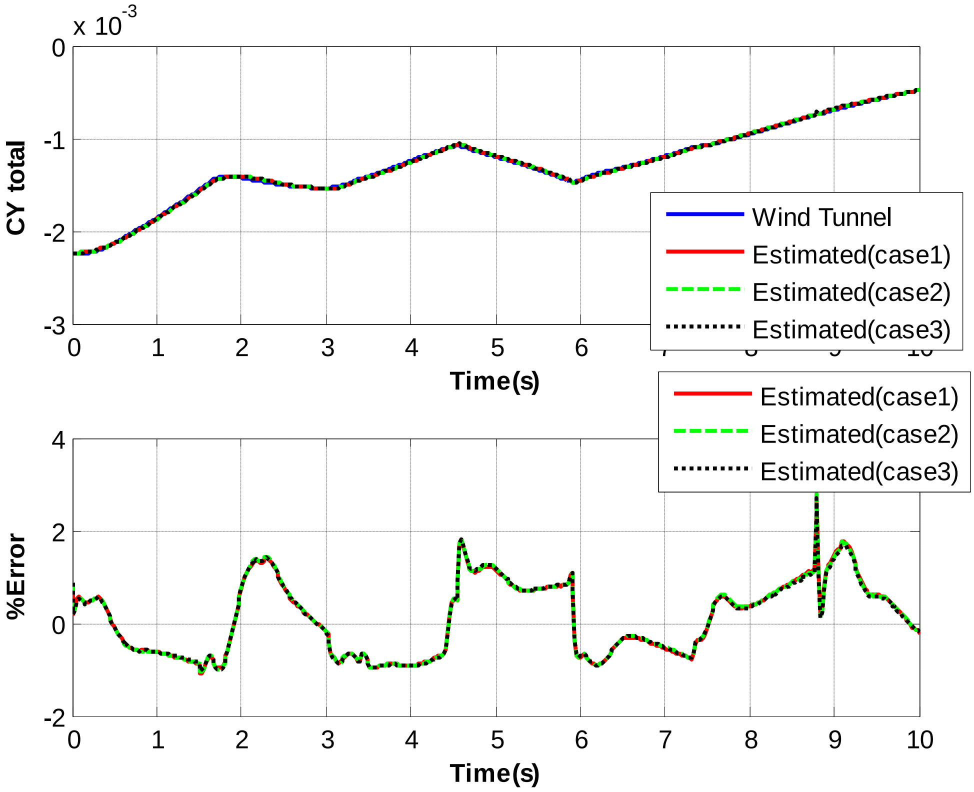

Fig. 4 The estimated total aerodynamic force coefficient C_Y

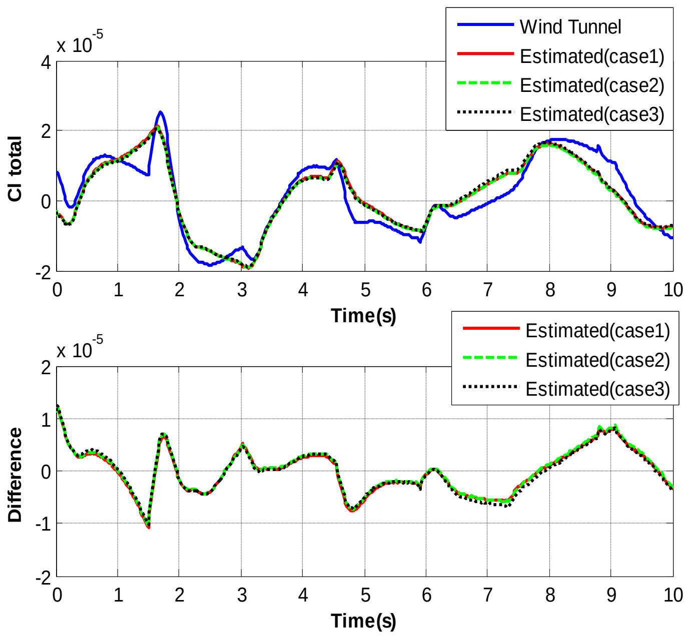

Fig. 5 The estimated total aerodynamic moment coefficient C_l

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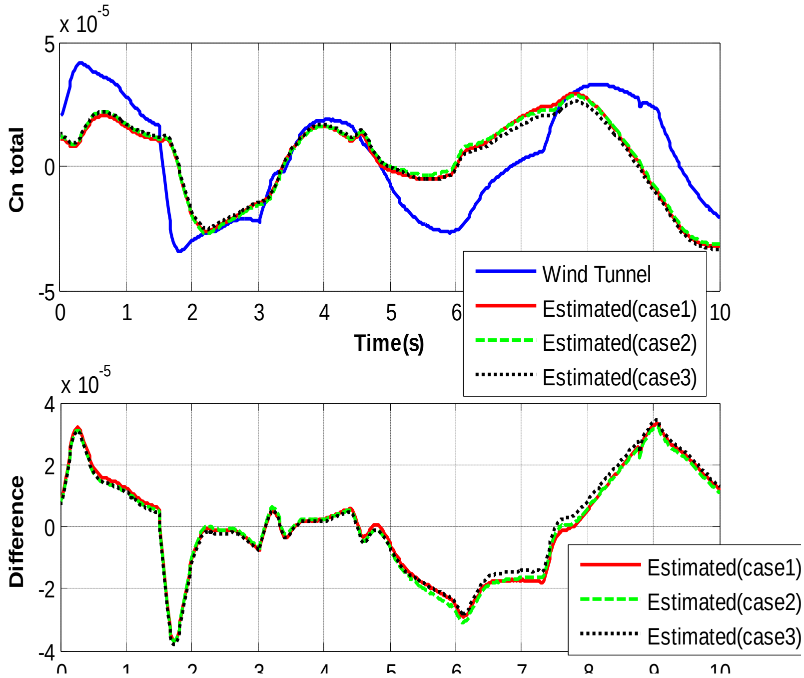

Fig.6.The estimated total aerodynamic moment coefficient C_n

V.CONCLUSION

Filter error algorithm is formulated and developed in MATLAB environment. With the developed algorithm lateral aerodynamic parameters are estimated with different noise levels .The estimated lateral aerodynamic coefficients are compared with wind tunnel prediction. Maximum of 3%, error, are observed in total aerodynamic force coefficients, 0.00001,0.000038 difference are observed in total aerodynamic moment coefficient.

REFERENCES

[1] R.E.Malne and L.W.Lfiff, "Identification of dynamic systems-applications to aircraft, part1-output error approach," *AGARDL flight test techniques series*, vol. 3, pp. 7-33, July 1986.

[2] Rakesh Kumar, "Lateral parameter estimation using regression", *International Journal of Engineering Inventions ISSN*, vol. 1,pp: 76-81, October2012.

[3] Luiz C.S.Góes, Elder M.Hemerly and Benedito C.O Maciel, "Parameter estimation and flight path reconstruction using output-error method",*24th international congress of the aeronautical sciences*,pp:1-10,2004.

[4] R V Jategaonkar and F Thieleckec, "*Aircraft parameter estimation, A tool for development of aerodynamic databases,"* Saadhanaa, Vol. 25, Part 2, pp.119-135,April 2000.

[5] R.V Jategoankar, "*Flight Vehicle System Identification : A time domain methodology* '', volume 216, 2006.