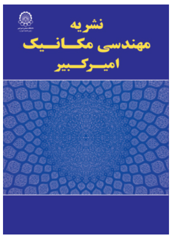

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Airplane Nonlinear Aerodynamic Model Identification in Spin Maneuver by Using Extended Multi Input Approach

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ABSTRACT: In this paper application of the multipoint aerodynamic model for parameter estimation in spin maneuver as a high-angle-of-attack and high-angular-rate fight regime was concentrated. The identification technique used to illustrate the approach is maximum likely hood with the equation error approach. The multipoint model comprises a set of new parameters describing the aerodynamic force distribution along individual surface components of the aircraft so using this method will be useful for spin aerodynamic modelling. The aim of this study is to demonstrate that this model allows coupling among the three force and three moment components, this means that the parameters associated with the six-component equations are thus treated simultaneously. Another advantage of this approach is that the model allows each individual force generating surface element of the aircraft to contribute independently to the total force and moment rather than some average of these contributions relative to the center of mass. The method is applied to measurements from spin fight test data conducted with a light general aviation aircraft and the results compared with conventional aerodynamic model. The results indicate that the method is capable of reproducing, with reasonable accuracy, the force and moment measurements obtained from a fight other than the one used in the parameter estimation.

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1- Introduction

The beginning of flight Spin maneuver is one of the most important air crashed reasons and many people lost their life because of this phenomenon. So studying specific nonlinear aerodynamic of conventional air plane in this maneuver is focused in this paper. Two fundamental methods are employed to estimate the desired aerodynamic parameters. The equation error method uses a postulated model for these forces and moments, the assumed functional form for their dependence on the motion variables that generate them, and seeks the estimated of the unknown coefficients in the postulated model, by minimizing the error between the measurement and the corresponding value calculated on the basis of the estimation (regression analysis). This model seems to work well for nonlinear fight regimes moderately in nature, but fails to provide general and robust results for the aerodynamics of maneuvers such as the spin. During such motions, the behavior of one surface element can be completely different from other one. In the conventional usage, these forces are lumped at the center of mass into one force, their sum, and hence one cannot expect that the regression could predict the behavior for one spin with data collected from another [1]. The resulting model is tailored to the specific data used for its computation, thus requires the data partitioning into ranges of the independent variables. The multipoint model seems to address this problem. This fact is demonstrated with a partial application of the method using simplified models in Ref. [2-4]. The work presented here is a more complete application of this modeling concept.

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2- Multipoint Model

The model used for the present work is based on strip theory. Because of the angular velocity, the dynamic pressure is a function of position on the surface of the aircraft. If η is introduced, upon which the local dynamic pressure and the angles of attack and sideslip are dependent, then x can be replaced by their derivatives with respect to η as shown in the following text.

$$F=\int_{\eta=\eta_1}^{\eta=\eta_2}\tilde{q}(\eta).C_F(\eta).\mathrm{c}(\eta).d(\eta) \tag{1}$$

$$\tilde{q}(\eta)=\tilde{q}+\frac{d\tilde{q}}{d\eta}\eta+\frac{1}{2}\frac{d^2\tilde{q}}{d\eta^2}\eta^2$$
$$C_F(\eta)=C_F+\frac{dC_F}{d\eta}\eta+\frac{1}{2}\frac{d^2C_F}{d\eta^2}\eta^2 \quad and \quad C(\eta)=\bar{\mathrm{c}} \tag{2}$$

Then by defining

$$\delta\tilde{q}=\frac{d\tilde{q}}{d\eta},\delta\alpha=\frac{d\alpha}{d\eta},dC=\frac{dC}{d\alpha}$$
$$\delta^2\alpha=\frac{1}{2}\frac{d^2\alpha}{d\eta^2},\delta^2\tilde{q}=\frac{1}{2}\frac{d^2\tilde{q}}{d\eta^2},\quad d^2C=\frac{1}{2}\frac{d^2C}{d\alpha^2} \tag{2}$$

By assuming C to be related to the local angle of attack substituting in Eq. (1) and rearranging a generic force component results from integrating the distribution $F(\eta)$ along the line of reference as follows:

$$F=\int_0^b F(\eta)d\eta=[C_1.\mathrm{k}_1+C_2.k_2+C_3.k_3+C_4.k_4+C_5.k_5].\bar{\mathrm{c}} \tag{3}$$

Where the k_i coefficients depend strictly on the kinematic state of the aircraft and the air density. The moment generated by this same force distribution is simply

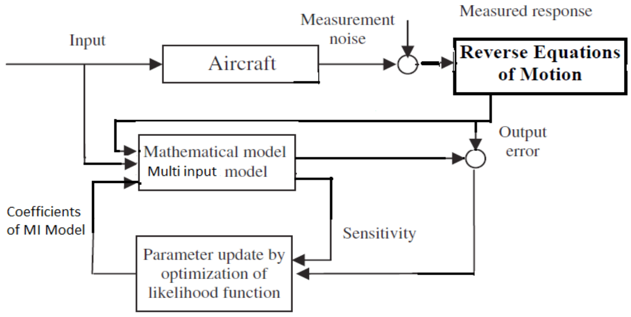

Fig. 1. Multi input identification diagram

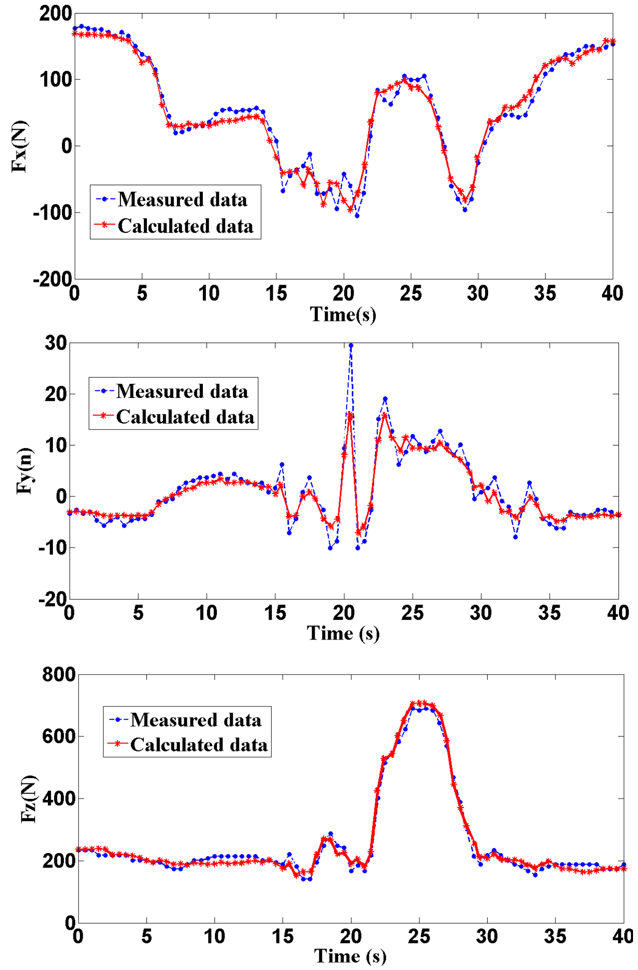

Fig. 2. Comparison of reconstructing forces for B maneuver by using A maneuver data

$$M = \int_0^b F(\eta).\eta d\eta = [C_1.h_1 + C_2.h_2 + C_3.h_3 + C_4.h_4 + C_5.h_5].\bar{c} \quad (4)$$

Note that k and h are kinematic factors dependent on the dynamic pressure and angle-of-attack distribution along h, thus they are known quantities for each measurement.

2- 1- Development of the model for regression

The available measurements of F_x, F_y, F_z, L, M, and N each correspond to measured values of linear and angular velocities. These velocities are used to compute the kinematic factors k and h, as shown earlier. Thus, each of the m measurements constitutes six equations for the computation of these components. They are the result of the kinematic relations giving the local angles of attack and sideslip and the dynamic pressure. The error is the difference between the measurement vector and calculated vector. The objective is to find C, which will minimize the error by maximum likelihood technique. C is obtained from where m is number of measurements in 40 seconds. For optimizing C matric coefficients we used output equation error algorithm with maximum likelihood technique. This is nonlinear optimization method that used widely in parameter estimation. The identification block diagram is shown in Fig. 1.

3- Results and Discussion

The measurements are available for several spins performed at the NASA Langley Research Center using a light single engine aircraft. The measurements used were made over a 40s duration at 0.1s intervals [5] .**The** spins used in this study are labeled A and B in the

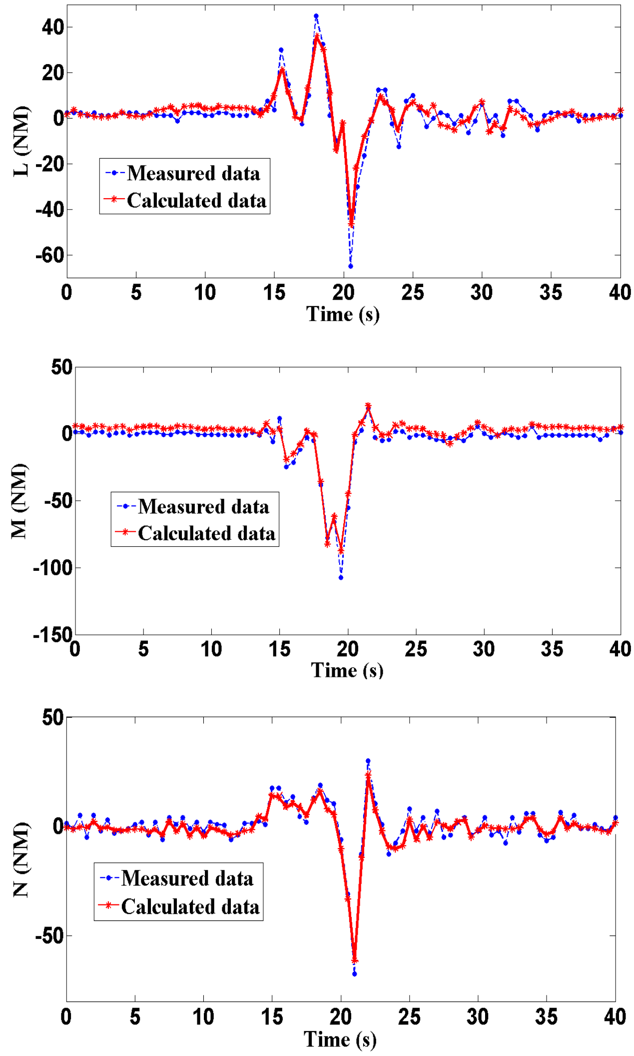

Fig. 3. Comparison of reconstructing moments for B maneuver by using A maneuver data

digital form of the data obtained from NASA Langley Research Center. The regression was performed using the data from spins A Fig. 2. In each case, the coefficients thus obtained were used, along with the control inputs' time histories and the kinematic quantities, to reconstruct the forces and moments for spins A and B. In addition, the model from spin A was used to reconstruct the data from spin B Fig. 3.

4- Conclusions

Application of the extended multipoint aerodynamic model for parameter estimation in spin maneuver was concentrated. The model used for the present work is based on strip theory. Current parameter estimation techniques for **aerodynamic** forces and moments are based on estimating the forces and their moments separately. While it is true that the moment equations form an independent set from the force equations, it must be kept in mind that it is the same pressure and shear stress distributions that generate both the forces and their moments. Therefore, the same coefficients described in this paper are estimated by using the force and moment equations simultaneously. This is made possible by the use of the multipoint model and its application to the various aircraft surface components. The preceding results indicate that this approach is a viable alternative to current models used in parameter estimation, when nonlinear flow conditions with large excursions in the vehicle motion variables exist. It was shown that estimation from one set of measurements successfully reproduced those from another flight.

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