Filter-Error Method for Aerodynamic Parameter Estimation of a Generic Future Fighter

Leonardo Murilo Nepomuceno[1)], Alain Giacobini 2[1)], Clécio Fischer[1)], Roberto Gil Annes da Silva[1)]

[1)]Aeronautics Institute of Technology, São José dos Campos - SP. Brazil

Introduction

The aerodynamic and structural optimization of fighter aircraft in recent years has pushed these aircraft to the limit. In order to achieve a great advance in performance and control, innovative configurations must be developed [1]. One way to evaluate an unconventional aircraft, in free flight, is to test a model on a reduced scale, to minimize risks and costs [2]. The subscale flight testing method is a reduced-size aircraft. It reproduces free flight like a manned or full-scale aircraft.

The most used technique for analysing flight dynamics is the construction of non-linear simulation model, [3]. To increase the accuracy of this model, data collected in flight is necessary to apply a system identification process. The identification codes present in this work were based on the algorithms proposed by Ravindra, a senior scientist at the German Aerospace Centre (DLR) [4].

Flight test data of a subscale fighter aircraft will be presented in this work. Data analysis indicates that noise is present due to air turbulence and makes modelling the aircraft difficult. Needing the application of methods to estimate the process noise, turbulence.

The Output-Error Method (OEM) has historically proven adequate for identifying flight vehicles. However, in this work, the OEM, which is not able to estimate the noise caused by air turbulence, will be compared with the Filter-Error Method (FEM), which estimates turbulence. The main objective of this work is to demonstrate that FEM applied to subscale aircraft increases the accuracy of the estimated model, since these aircraft are more susceptible to turbulence.

GFF Subscale

In 2006 Saab Aeronautics, the Swedish Defence Research Agency (FOI), Volvo Aero, Linköping University and the Royal Institute of Technology (KTH) decided to develop a concept of a future fighter, the Generic Future Fighter GFF. The subscale model was built at Linköping University under the Future Aircraft Design and Demonstration (FADEMO) project. The subscale GFF has a wingspan of 1.47m, while the concept full-scale aircraft has a wingspan of 10.5m.

The Generic Future Fighter (GFF) is a subscale platform, i.e. a 14% scaled model, *Figure 1*. A cooperation signed between the University of Linköping (Sweden) and ITA (Brazil) allows for the flight test of the GFF. While the Swedish university is responsible for operating and developing test procedures and acquiring flight test data, ITA [5] is responsible for implementing the system identification process with the acquired data.

System Identification

The Filter-Error Method process is presented in the Figure *2*. Where, Z is the data measured during the flight and $\tilde{y}$ is the output vector of the system based on states estimated by the Kalman filter.

Figure 1 – GFF subscale during flight tests at Sweden (Courtesy of Linköping University)

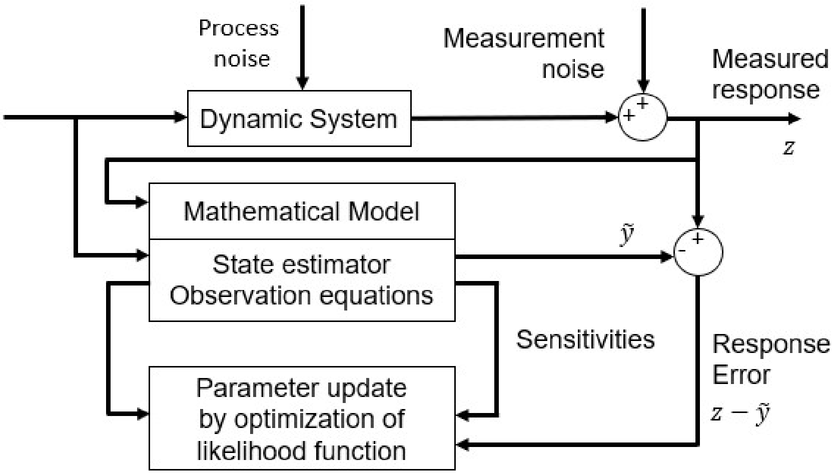

Figure 2 – Filter-Error Method [Ravindra]

According to Sobron (2021), the application of the Filter-Error Method to identify the GFF model is possibly the most adequate process due to turbulence.

Results

Figure *3* presents time histories of two output variables, true airspeed and angle of attack. Two variables related to air flow. In this figure, the Output-Error Method was used for model estimation, where the red line represents the estimated model and the blue line represents the data measured in flight.

Figure *4* shows the same flight phase of the GFF. However, the red curve presents the model estimated with the Filter-Error Method, where turbulence is considered in the prediction of the parameters. Comparing the two figures, it can be seen that the result of the Filter-Error Method was closer to the data collected in flight.

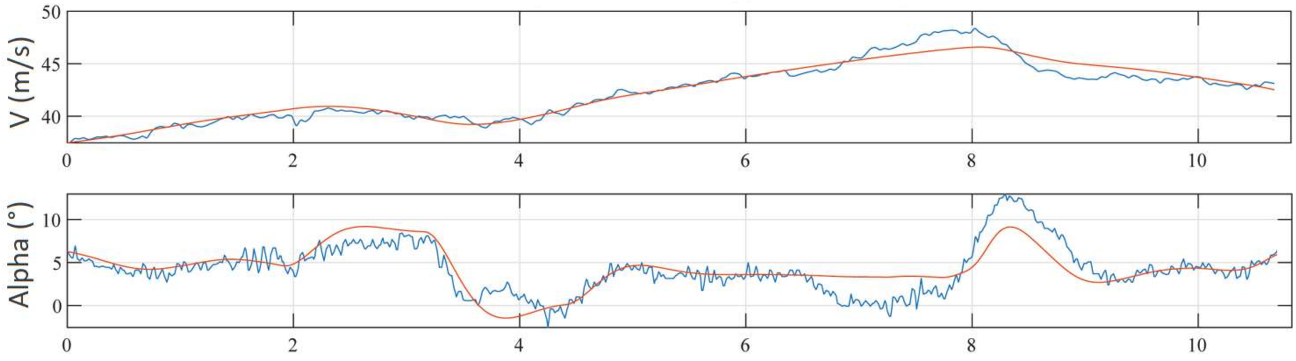

Figure 3 – Output Error Method, without turbulence prediction

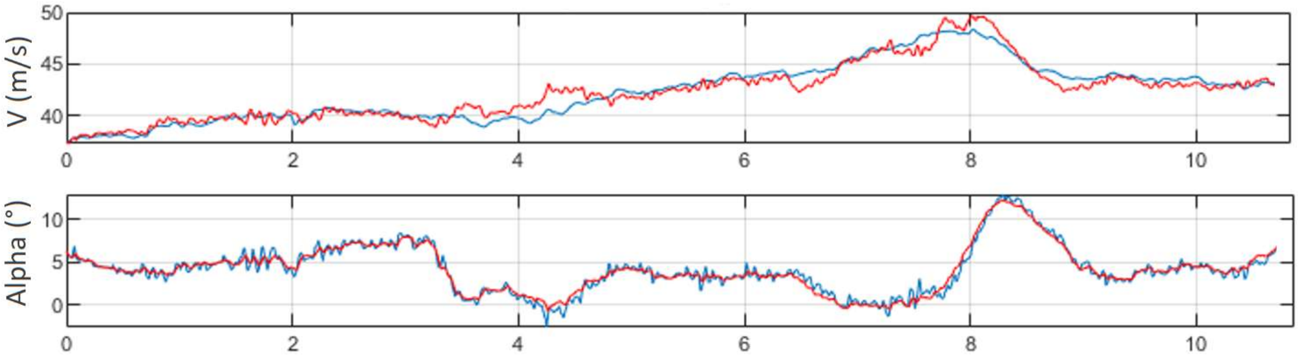

Figure 4 – Filter Error Method, with turbulence prediction

Conclusion

The subscale method for fighter design can add information and model the aircraft in some regions of the flight envelope. It is an important tool for analysing and developing aircraft with non-conventional configurations. Considering the results presented, to ensure a good accuracy of the model, the use of the Filter-Error Method proved to be more suitable for subscale fighter applications.

References

1. Monteiro, D. M., Nepomuceno, L. M., Silva, R. G. A., Souza, M. S., Silvestre, F. J., Kruss, P. and Sobron, A.. 2017. Sub-scale Flight Test Model Development and Testing as a Tool for Unconventional Aircraft Design. Aerospace Europe 6th CEAS Conference.
2. Chambers, J. R, 2009, "Modeling Flight", 1 st, NASA, Whashington D.C.
3. Kulkarni, A. R., Varriale, C., Voskuijl, M., Rocca, G. L. and Veldhuis, L. M.. 2019. Assessment of Sub-scale Designs for Scaled Flight Testing. AIAA Aviation. Dallas, Texas.
4. Jategaonkar, R. V.. 2015. Flight Vehicle System Identification: A time-Domain Methodology. AIAA. Reston, VA.
5. Zúñiga, D.F.C., Souza A.G., Góes L.C.S.. 2020. Flight Dynamics Modeling of a Flexible Wing Unmanned Aerial Vechicle. Journal od Mechanical System and Signal Processing.
6. Sobron, A.. 2021. On Subscale Flight Testing. Doctoral Dissertation. Linkoping University.