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Identification of Longitudinal Aircraft Dynamics by Process Model using MATLAB/SIMULINK

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Abstract—System-identification methods compose a mathematical model, or series of models, from measurements of inputs and outputs of dynamic systems. The estimated models allow the characterization of the response of the overall aircraft or component subsystem behavior. This paper discusses the use of System Identification Toolbox of MATLAB/SIMULINK for the estimation of aircraft flight dynamics in longitudinal channel. The data extraction, model selection and estimation of aircraft dynamics by process modeling along with data validation, time and frequency response analysis is illustrated using the system-identification simulation environment.

Keywords—System Identification, Process model, MATLAB/SIMULINK.

I. INTRODUCTION

Design and analysis of control system is one of the most significant and imperative field of engineering and technology. Assorted methods [i] have been inhabited from the various fields of control engineering for enhanced performance. To design a better control system, the comprehension of system dynamics is indispensable.

The system dynamics can be articulated in form of differential equations developed from physical principles or from transfer function models, which expresses the input-output property of the system. Some of the external parameters which affect system behaviour can have unknown or uncertain values, for example vortex formation on the control surface of the aircraft. In practical scenario, enhancement in the control system performance is constrained due to insufficient knowledge of the system behaviour or dynamics. Therefore estimation of the precise behavioural aspect of system is mandatory.

System identification is a full life-cycle technology that supports aircraft flight-control system development from design specification through flight-test optimization. Significant reductions in development time and costs are realized by tracking open and closed-loop dynamic response characteristics through the development process. System identification is especially effective in providing a transparent and integrated understanding of handling-qualities characteristics and system stability. Considerable improvements in system performance are facilitated by the rapid availability of accurate end-to-end and subsystem dynamic models.

In this paper, section II illustrates the system identification and steps involved in estimation of dynamic behavior of the system. Section III deals with input-output data generation by experiment simulation, model selection and estimation by process modelling using MATLAB/SIMULINK and data validation. Results are discussed in Section IV and conclusion is provided in Section V.

II. SYSTEM IDENTIFICTION

System identification is the art and science of building mathematical models from measured input-output data. It allows estimating mathematical models of a dynamic system based on measured data. Essentially by adjusting parameters within a given model until its output coincides with the measured output. The most widespread models are difference equations descriptions, such as Process model, ARX and ARMAX models, as well as all types of linear state-space models. [ii] discusses the procedure of system identification using ARX model. The dynamics of the system can be estimated by using either parametric or nonparametric identification methods.

Parametric Identification Methods are techniques to estimate parameters in given model structures. The numerical values of the parameters are find in an iterative manner that give the best agreement between the estimated output and the measured output.

Nonparametric Identification Methods are techniques to estimate system behaviour without any model structure. Typical nonparametric methods include Correlation analysis, which estimates a system's impulse and step response. The spectral analysis is useful in frequency response estimation. The procedure to determine a model of a dynamical system from observed input-output data involves three basic ingredients:

• The input-output data

• A set of candidate models (the model structure)

• A criterion to select a particular model in the set, based on the information in the data (the identification method).

III. INDENTIFICATION PROCESS

A. *Input-Output data collection*

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The measurement data can be conceived by recording of input and output parameters from a live system. In this paper, we consider a conventional transport aircraft [iii] transfer function for collection of input-output data. The measurement experiment is carried out using MATLAB SIMULINK [iv] and block diagram representation is shown in Fig 1 with longitudinal aircraft transfer function given as below

$$\frac{\theta(s)}{\delta_e(s)} = \frac{(s+3.1)}{s(s^2+2.8s+3.24)}$$

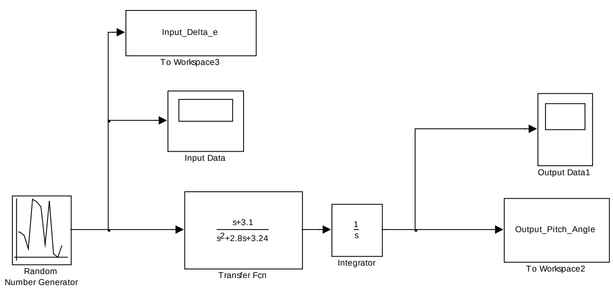

Fig.1. Experiment Simulink block diagram

The input and output data generated from simulation is shown in Fig 2 & 3respectively.

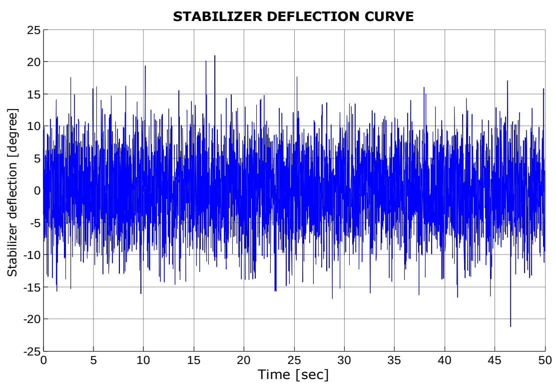

Fig.2. Aircraft stabilizer deflection input curve

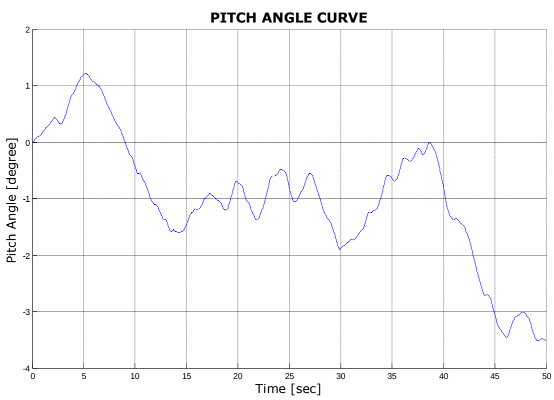

Fig.3. Aircraft pitch angle output curve

B. *Model Selection and Estimation*

This paper describes the system identification technique using process modelling. Process model allows to generate simple, continuous-time, dynamic linear models - characterized by static gain, time constants, and time delays. System Identification (SI) toolbox GUI of MATLAB have real and imaginary poles, zeros, delay and integrators as standard blocks. The SI GUI is opens by command ***ident*** on the command prompt.

The time domain input and output data is imported from the MATLAB workspace by popup menu ***import data*** in SI GUI window. There is a provision in SI GUI window for examining and pre-processing the imported data set. However, for the sake of originality we have discarded the pre-processing stage.

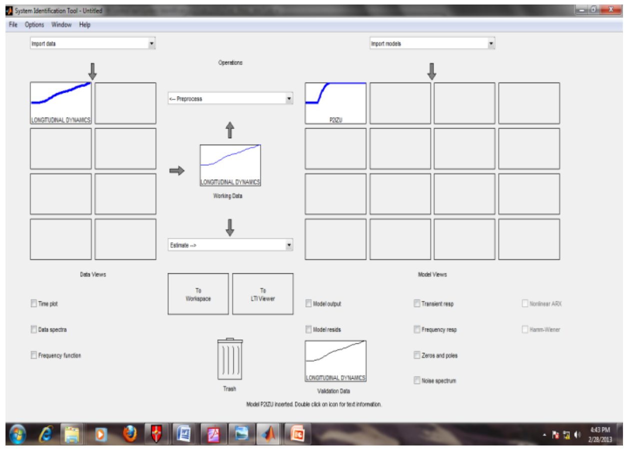

Fig. 4 System Identification Toolbox GUI window

In this paper integrator, zero and undamped poles are considered for estimation. The selected transfer function coefficients are then estimated by using popup menu ***Estimate -->Process models***. The estimated process model and its coefficients can be observed in window shown in Fig 5.

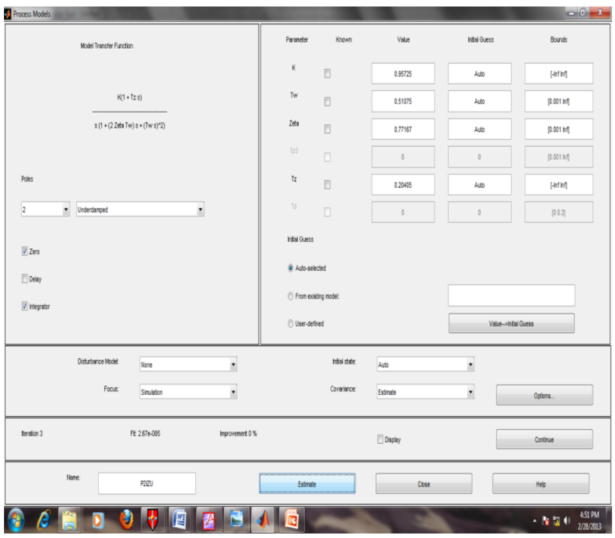

Fig. 5 Estimated parameters in System Identification Toolbox GUI window

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C. *Model Validation*

After the model estimation the verification need to be carried out for model perfectness. The data used to validate the accuracy of the model is shown by an icon, labelled Validation Data under ***Model Views***. In this paper we have verified the estimated model by feeding the same aircraft stabilizer deflection input and obtained aircraft pitch angle output and discussed in section IV.

IV. RESULTS AND DISCUSSION

From Fig 6, it is clear that the waveform of measured data and estimated model output data are basically the same and the matching degree is about 95.54 percent. The pole-zero analysis of estimated model is also carried out in SI GUI and shown in Fig 7.

$$\frac{\theta(s)}{\delta_e(s)} = \frac{0.75(s+4.9)}{s(s^2+3.02s+3.83)}$$

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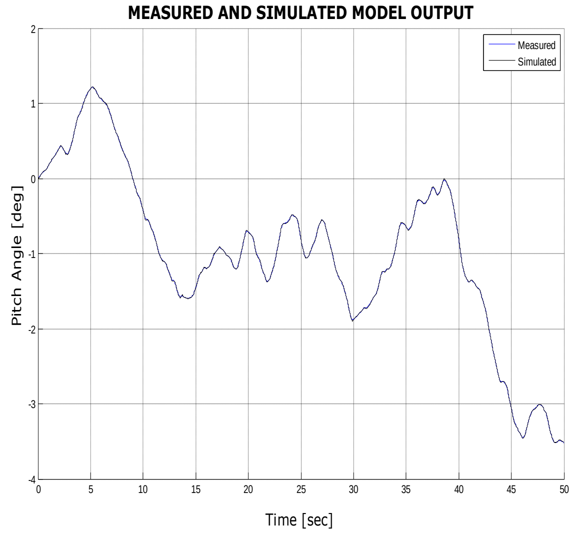

Fig. 6 Comparison of measured and estimated system output

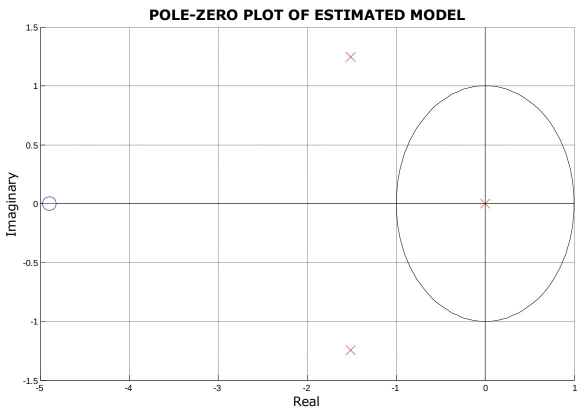

Fig. 7 Pole-zero plot of estimated system model

Apart from the above, time and frequency domain behaviour of the estimated model is also carried out. The results shown in Fig 8 & 9 reveal that the estimated model's step and frequency response is identical with the actual model response.

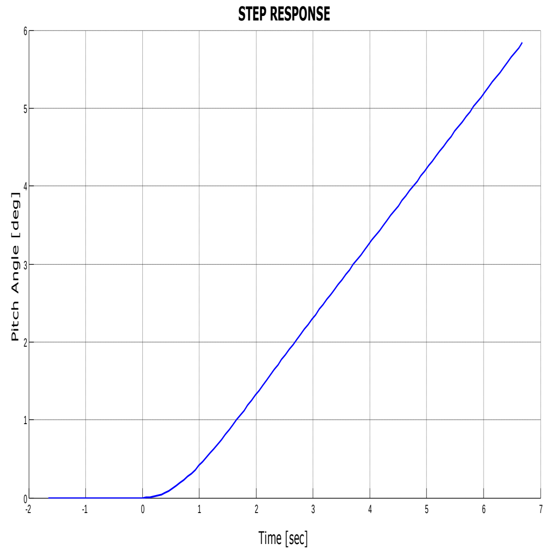

Fig. 8 Step response of estimated system model

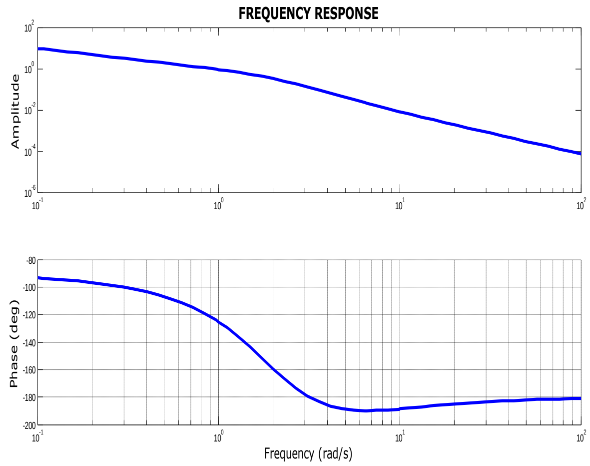

Fig. 9 Frequency response of estimated system model

V. CONCLUSIONS

Without prior knowledge of system behaviour, it is difficult to design good control system. For a flying platform, this can be problematic because poor control can cause the system to lose stability and crash, potentially damaging the aircraft. Even when stable gains have been implemented, it is still a time-consuming task to optimize the gains because it involves testing and retesting new gains on the aircraft. By characterizing the dynamics of the aircraft, the iterative guess-work in selecting control gains can be completely removed. In this paper, we have identified the aircraft dynamics with 95.54 percent accuracy using process modelling.

The results indicate that process modelling is best suitable candidate identification of longitudinal aircraft dynamics involving integrator, zero and undamped poles.

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Biography

Jitu Sanwale received the B.E. degree in Electronics & Instrumentation Engineering from SGSITS, Indore in 2006. He also received the M.Tech degree in Communication Systems from IIT Roorkee in 2008. He is an associate member of Aeronautical Society of India (AeSI) and Institution of Electronics and Telecommunication Engineers (IETE). He joined the Aircraft Research & Design Centre, Hindustan Aeronautics Limited in 2008 as a design engineer. Presently, he is working as Deputy Manager (Design). His areas of interest include Inertial and Global Positioning System, Radio Navigation, Flight Control System and Adaptive Signal Processing.

Dhan Jeet Singh received the B.Tech degree in Electronics & Communication Engineering from BIET, Jhansi in 2005. He is a life time member of Aeronautical Society of India.He joined the Aircraft Upgrade Research & Design Centre of Hindustan Aeronautics Limited in 2005 as a design engineer. Presently, he is working as Manager (Design) in Flight Controls & Navigation group of Design Electrical department. His areas of interest are radio navigation, flight control system and system identification.