Abstract

Characterising Angular Accelerometers using a Two-Axis Motion Simulator

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Fault-Tolerant Flight Control (FTFC) systems reconfigure aircraft flight control laws to help restore a controlled flight and preserve acceptable performance under system faults. This method does not rely on an accurate and full aerodynamic model, but only requires an estimate of the control effectiveness and an additional reconfiguration mechanism to the control laws. Recent developments lead to FTFC systems that require angular acceleration feedback. With the angular accelerometer being at the very heart of the control laws, to have proven and well-understood sensors is essential to increase the operational performance of a post-failure aircraft.

The thesis aims to investigate how an angular accelerometer can be evaluated and calibrated in a systematic fashion. The standard for evaluation is, at the moment, the turntable or motion simulator system. Unfortunately, the angular acceleration is less precise compared to angular rate due to the design of the current motion simulator which typically aims for superior performance in providing static operation, i.e., a constant rotation rate without rotational acceleration. Moreover, rigorous examination procedures for this new type of sensor are not yet well-established, which mainly concerns isolating the possible test equipment's issues from sensor inaccuracies. With the dynamic angular operation and method limitation in mind, this dissertation therefore focuses on how to characterise angular accelerometers using a 2-axis motion simulator effectively.

The goal is achieved by first defining a general measurement framework that describes internal and external disturbances, and the relation between all subsystems in the measurement set-up as required to perform angular accelerometers experiments. Subsequently, a scale factor calibration of the angular accelerometer output to a known standard using the synchronised measurement data of a sinusoidal angular acceleration amplitude profile was the second objective. The evaluation is performed over the standard estimated angular acceleration of the turntable and a refined approximate of angular acceleration utilises Sliding-Mode Differentiation (SMD). The third aim was to obtain a frequency response measurement that model the angular acceleration feedback information accurately with experiment conditions designated within the motion simulator operational limit, and the angular accelerometer technical specifications. The Frequency Response Function (FRF) of the systems for different angular acceleration amplitude, is then identified from the discrete Fourier transform of selected input and output pairs to obtain transfer function models, proposed with and without a separate delay term. The fourth and last objective addressed in this thesis is the inspection of the angular accelerometer input axis misalignment in the form of a 3-axis Angular Accelerometer Measurement Unit (AAMU). Results show that the input motion is detected in both non-sensitive axes, indicating the presence of misalignments. Correction to the voltage response signal of the angular accelerometer is performed using the misalignment angle of the sensitive axis.

This research has demonstrates that the commercially available angular-position based turntable can indeed be utilised to perform an in-depth evaluation of angular accelerometers. The acquired knowledge contributes towards a general method of characterising such sensor, which encompasses not only accurate calibration and modelling, but also modified procedures in dealing with specific angular acceleration motion. Despite rising interest on angular accelerometer, this topic still leaves many possibilities to explore, mainly, in connection with developing a common ground in angular accelerometer calibration by examining different sensors using various motion simulators. In relation with fault-tolerant flight control, the application of the sensor model obtained in this thesis in the control system design could provide validation on model performance. Incorporating effects of temperature in dynamic calibration is also crucial to consider in the future, which calls for the integrated environmental chamber on the turntable. Finally, the development of a state-of-the-art motion simulator that is built specifically to test angular accelerometer is worth an investigation as well.