UH-60 Black Hawk Disturbance Rejection Study for Hover/Low Speed Handling Qualities Criteria and Turbulence Modeling

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Abstract

This paper will discuss the airborne flight test of the Sikorsky UH-60 Black Hawk helicopter in turbulent conditions to determine disturbance rejection criteria and develop a low speed wind/turbulence model for helicopter simulation. An overview of the major elements of the paper is given below:

Background Information

The effects of wind/turbulence on helicopter handling qualities are not well developed nor quantified. It is widely recognized that as the level of wind and turbulence increases, task performance may be compromised and/or pilot workload increased lending to a degradation in handling qualities and safety. Although NRC Canada (reference 1) has performed a disturbance-rejection handling qualities study, very few parametric wind/turbulence handling qualities studies exist. In fact, there is little or no supporting data for the disturbance rejection requirements in ADS-33D-PRF (reference 2), the US Army handling qualities requirements for military rotorcraft. One reason for the lack of wind and turbulence effects in the rotorcraft handling qualities data base has been that wind and turbulence models have been inadequate, not validated, and/or are difficult to implement and use. And yet, there has been much interest in modeling the effects of wind and turbulence on rotorcraft flight dynamics to include complex "rotating-frame turbulence" modeling.

Problem Statement

The quantitative requirements of ADS-33 are divided into two flight regimes, Hover/Low Speed and Forward Flight, and further divided by axes of control. These requirements are separated not only by response amplitudes but also for control inputs versus disturbance inputs. The requirements for short-term pitch, roll, and yaw responses to disturbance inputs are the same as the control response bandwidths. There are no disturbance rejection requirements in the heave axis. For the qualitative flight test demonstration maneuvers in ADS-33, although there are maneuvers which are only evaluated in calm winds, there are several maneuvers that are to be evaluated both in calm winds and in moderate winds. There are little or no supporting data for either the disturbance rejection requirements or the moderate wind effects on the flight demonstration maneuvers. This disturbance rejection study is providing data in these areas to support/refine ADS-33.

In the area of wind/turbulence modeling, the predominately used fixed-wing turbulence (Dryden) model is not satisfactory for rotorcraft and must be carefully tuned to avoid numerical problems. That is, since the turbulence model scaling parameters are a function of the vehicle velocity, some arbitrary non-zero velocity must be selected to avoid dividing by zero as the helicopter comes to a hover. Currently, research is ongoing on blade-centered and cyclo-stationary random processes for treatment of rotorcraft turbulence modeling, but these models are too complex for handling qualities investigations. This disturbance rejection effort can provide data to develop a realistic and simple empirical model. Once this empirical model is developed, coupling this to the UH-60 GenHel math model can provide the tool needed to develop a UH-60 gust response model. This capability could be not only used for parametric studies of disturbance rejection but also for future rotor state flight control trade-studies. Figure 1 shows an approach schematic for these efforts and lists some of expected payoffs.

Flight Test Objectives/Conditions

The flight test program (reference 3) consists of two phases: (1) hover tasks on the leeward side of a building to collect data in a turbulent-rich environment; (2) ADS-33 low speed Mission Task Elements (MTE) in windy conditions to assess the wind effects while performing the Precision Hover and Pirouette maneuvers from ADS-33.

The phase one hover task was conducted at the Coast Guard Air Station San Francisco on the leeward side of the aircraft hangar to take advantage of turbulence generated by the predominant winds across this blunt body (figure 2). Test day conditions for the first data flight were approximately 15-20 knots across the building with +/-30% turbulence variation. Hover altitude was targeted based on flow theory around blunt objects, and the pilots found two distinct locations where the turbulent effects were maximized. The pilots executed two hover tasks to different performance standards (tight and relaxed) and a "hands off" hover minimizing pilot control loop closure.

The second phase of flight test will be conducted at Moffett Field. Thus far data have been collected for the Precision Hover and Pirouette in calm and light winds for multiple pilots, and the goal is to gather additional data in moderate to strong wind conditions.

Preliminary Results

The paper will detail the data analysis procedure, and some preliminary results are presented here. The flight test data were initially examined in terms of pilot and aircraft cutoff frequency to determine the frequency content trends with varying position tolerance. Figure 3 presents both pilot control input and mixer input cutoff frequencies plotted against approximate hover position tolerances. The figure indicates that, with a tighter tolerance, the cutoff frequency increases. Figure 4 presents pitch rate time histories from the aircraft test data, transfer function model (generated from flight test control inputs) and the resulting remnant due to the turbulent air mass. Current effort is focused on developing an inverse model of the UH-60. The initial approach will be to extract low-order on-axis transfer function models from recent frequency response flight test data for the project test aircraft.

The preliminary results of the ADS-33 evaluation show some variations in pilot ratings (reference 4) with increasing wind conditions. These maneuvers, Pirouette and Precision Hover, were conducted in winds varying from 4 to 16 knots. Flight test is ongoing and as of yet the data are inconclusive as to the pilot rating and bandwidth requirement effects due to the presence of atmospheric disturbances.

The paper will summarize the efforts of the test team, including lessons learned, in the process of generating the simplified turbulence model. The intention is to present a finalized model and validate it through use of a piloted simulation using RIPTIDE (Real-time Interactive Prototype Technology Integration/Development Environment). Verification or refinement of the current ADS-33 disturbance rejection requirements will be included as well as any recommendations for further research.

References

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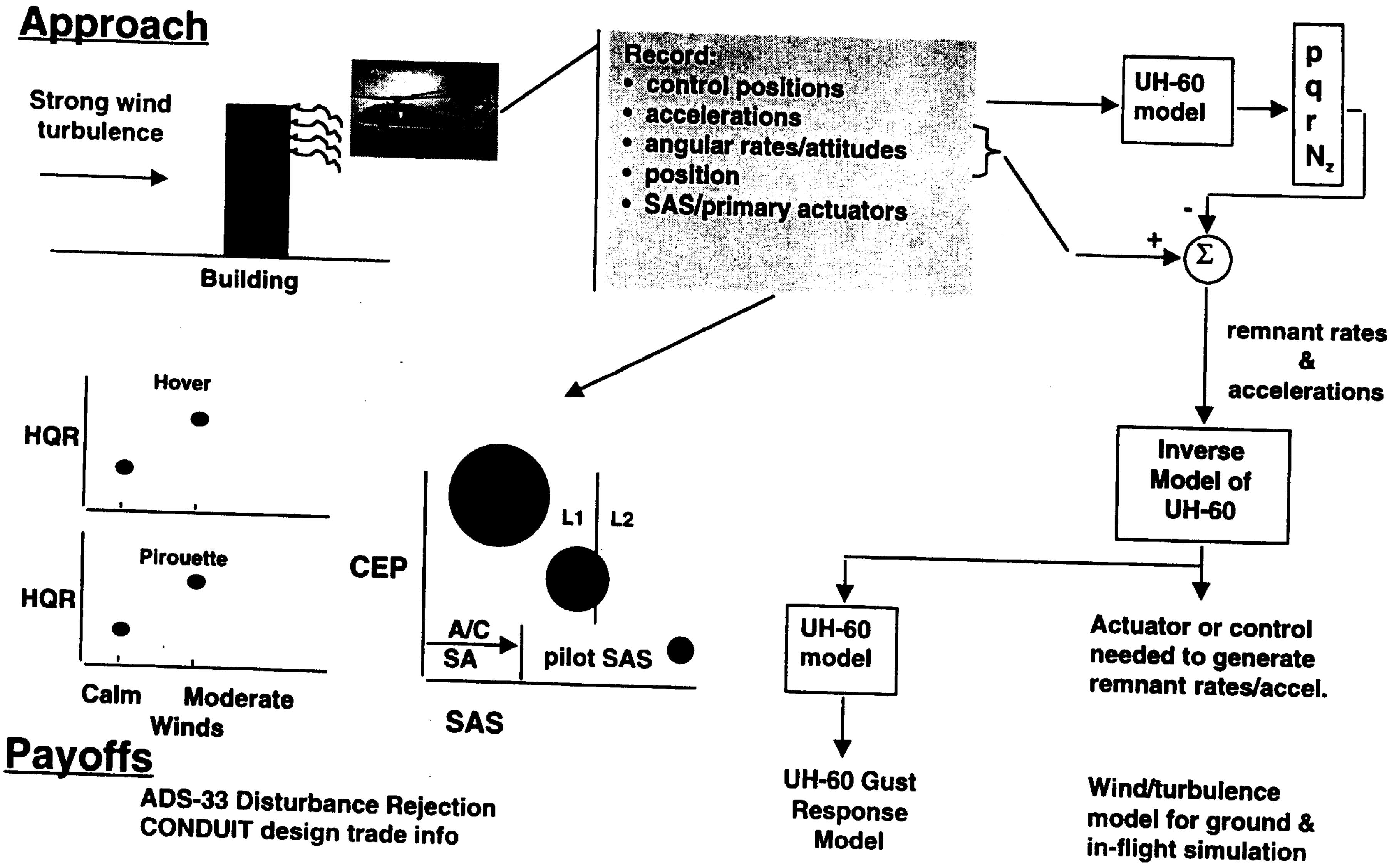

Figure 1. Schematic for overall approach and expected payoffs from disturbance rejection study.

Figure 2. UH-60A Hovering on Leeward Side of CGAS Hangar

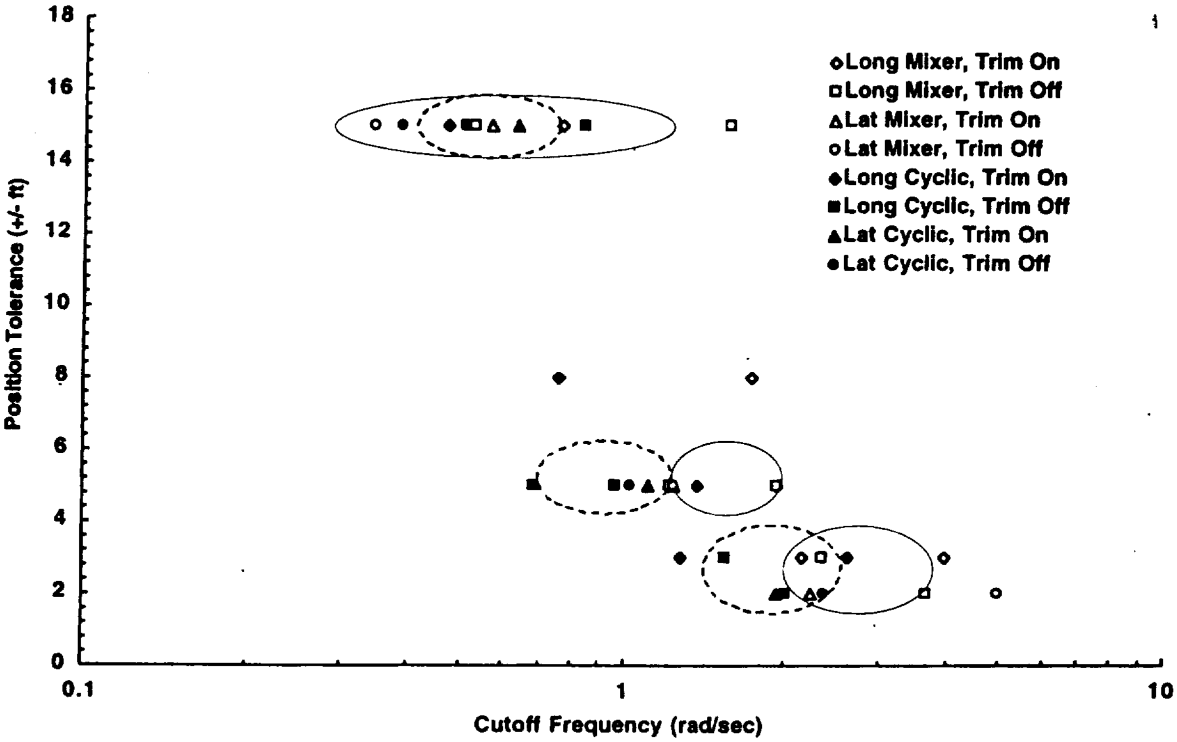

Figure 3. Mixer and Cockpit Control Cutoff Frequency (on wind axis)

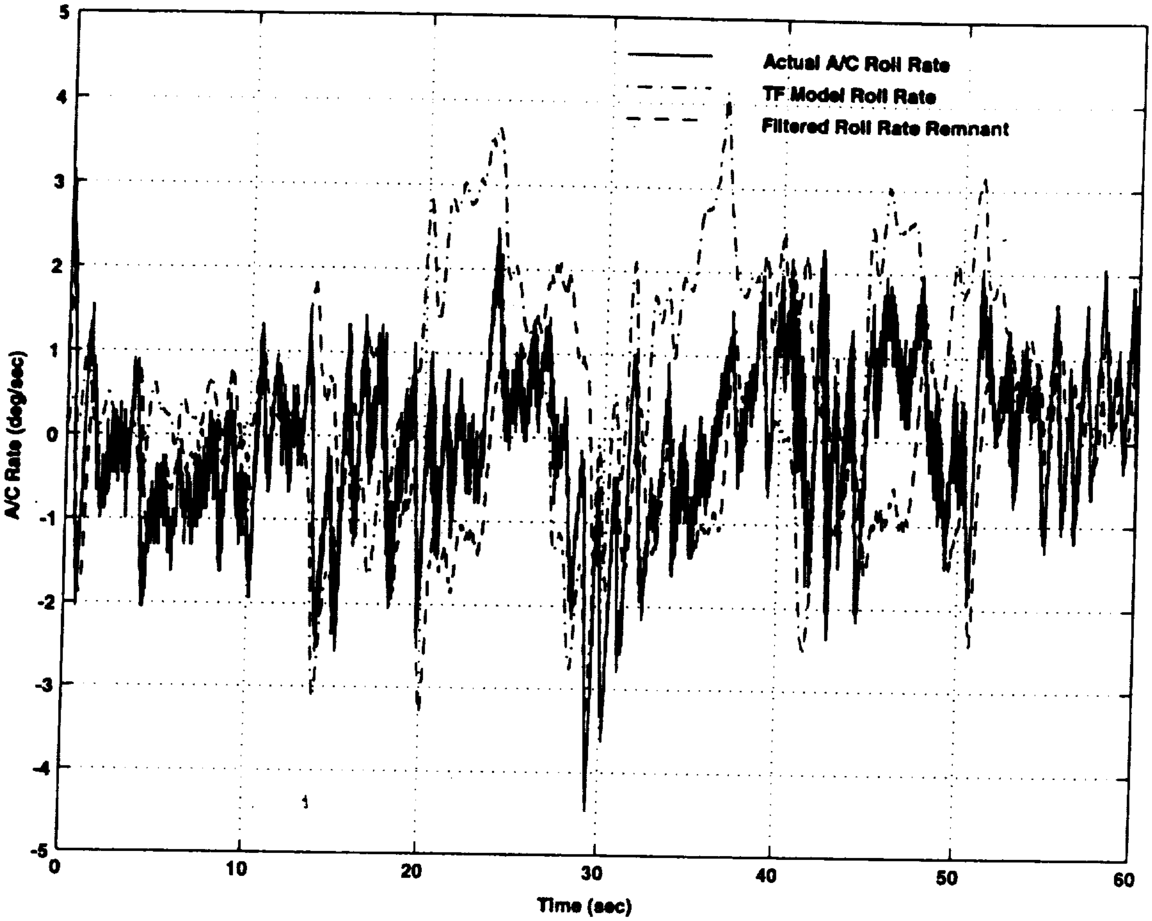

Figure 4. Aircraft roll rate time histories for 48 foot hover, into wind, open loop.