Dynamic Interface Modelling and Simulation. Part 1: Preparation and Analysis for High-Fidelity Helicopter-Ship Flight Simulations

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Maritime helicopters are routinely deployed with modern combat ships. The recovery and launch of helicopters to and from ships at sea is regarded as one of the most demanding and dangerous environments in which a pilot may operate [1]. The ship's motion, combined with the air flow moving over and around the ship's superstructure, known as the ship's airwake, contribute to overall pilot workload [2]. To ensure the safety of pilots and crew operating within the Helicopter Ship Dynamic Interface (HSDI), a series of launch and recovery tests are completed with the ship and helicopter at-sea for winds of different strength and direction to determine the Ship-Helicopter Operating Limits (SHOL). An example of a SHOL is shown in Figure 1 indicating the boundary outside of which the combination of wind over deck conditions (magnitude and direction) make it unsafe for the helicopter to land. Through the use of Modelling and Simulation (M&S), at-sea conditions can be recreated for a given ship and used for analysis of both the air flow in which the aircraft is operating, and for real-time piloted flight in a simulated environment [3]. This paper presents the development of individual elements required for flight simulation within the HSDI and the in-house tools developed to inspect the air flow prior to SHOL testing at-sea.

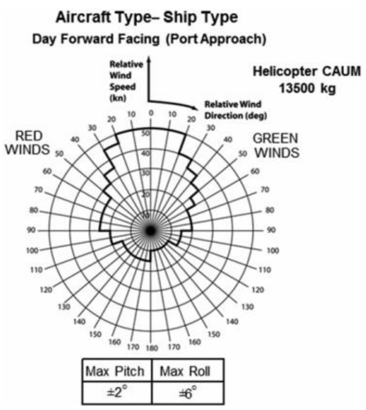

Figure 1: Example SHOL showing wind-over-deck envelope

In preparation for high-fidelity HSDI simulations, the ship's airwake and deck motion, two of the larger contributors to pilot workload, must be included. Detached Eddy Simulation (DES), a Computational Fluid Dynamics (CFD) method, is used to model the unsteady air flow over and around the flight deck [4]. To provide confidence in the CFD method the computed solution of a large aircraft carrier's airwake was compared with experimental measurements [5], a sample of which is shown in Figure 2. The addition of realistic ship motion is also necessary as it may have a large impact on pilot workload [6]. Two approaches have been adopted to model the ship motion: the first is to scale previously recorded ship motion to the ship size and sea state, the second is to compute the ship motion using a potential-flow code, ShipMo3D [7].

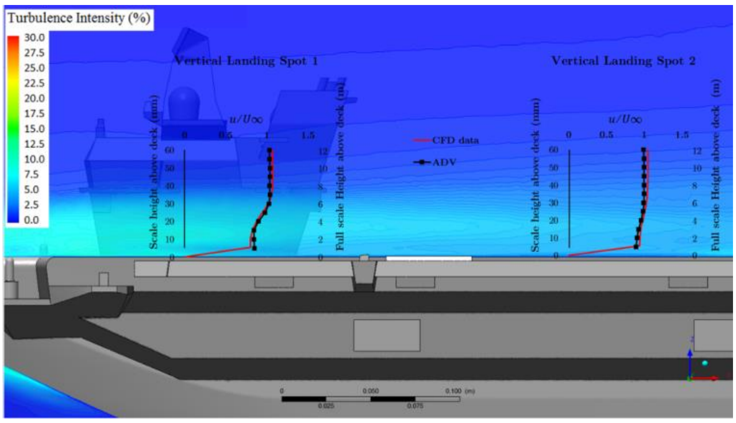

Figure 2: Experimental u-velocity measurement comparison with CFD solution

A number of tools are available to assess the air flow field over the flight deck for both ship design and ship-helicopter operations: the Virtual AirDyn (VAD), SIMSHOL, and Pilot-in-the-loop simulated flight trials (PSFTs). The VAD is a technique developed at the University of Liverpool (UoL) to measure the impact of a ship's airwake on a helicopter by integrating the unsteady velocities with a helicopter flight dynamics model [8]. SIMSHOL is a predictive simulation tool that presents an objectively optimized human pilot modelling technique within an integrated pilot-vehicle-environment that represents the HSDI [9]. PSFTs for SHOL testing are conducted in the UoL's full-motion flight simulator in which a helicopter flight dynamics model is integrated with the ship's airwake in a simulated environment of the ship at-sea with ship motion applied; this allows a test pilot to assess the flying conditions due to the ship airwake and ship motion without the risk associated with at-sea assessment. The assessment is provided by the pilot in the form of workload ratings. Three tools are therefore available to assess the effect of the ship's airwake on a helicopter prior to at-sea flight trials, as illustrated in Figure 3. While the simulation tools are not expected to replace the trials, they can inform the planning and conduct of the trials and, if applied early enough, they can inform the aerodynamic design of the ship's superstructure. The paper will present each of the methods along with practical applications.

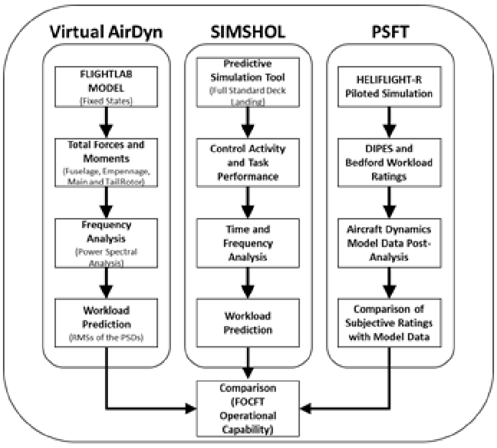

Figure 3: Flow diagram showing how modelling and simulation is used to evaluate the ship/helicopter dynamic interface prior to sea trials.

The confidence in the use of the PSFTs depends upon the identification of the fidelity requirements of the critical M&S elements integrated into the HSDI simulation environment. This is detailed in a companion paper (Part 2 [10]), which reports the results from a series of experiments that have been conducted in the UoL's HELIFLIGHT-R simulator aimed at developing robust simulation fidelity criteria for high-fidelity shipboard operation.

References

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