ABSTRACT

The warfighting prowess of any Navy, from the era of the sailing ships, till the dawn of the twentieth century, has been dominated by the gun. However, the development of the aeroplane in the early 1900s, gave a new impetus to naval warfare, with these aircraft being the new weapons of war. These aircraft extended the striking range of maritime forces, limited hitherto by the range of their guns, by an order of magnitude, which was beyond the expectations of any naval ship commander. This led to a paradigm shift in the way naval battles were fought and led to the replacement of the formidable battleships, the capital ships of yore, with a new type of warship, till then unheard and unseen – the aircraft carrier. However, landing an aircraft on an aircraft carrier has always been problematic and challenging for the naval aviation pilots, due to constraints in the runway length and size as compared to land based air fields. Added to these constraints, is the effect of the turbulence generated by the various elements that constitute an aircraft carrier, namely the hull, flight deck configuration and the island shape, aft of the carrier, along the glideslope path of pilot approach, traditionally known as the burble effect.

The naval architects and ship designers, primarily responsible for the design of an aircraft carrier, at present, do not have adequate data for assessing the aerodynamic impact of the flight deck and island configuration on glideslope path and pilot workload. These days, CFD studies may be integral part of the preliminary ship design. However, even with advent of CFD for preliminary ship design studies, there have been no systematic parametric studies conducted on the aerodynamic effect of various constituents of an aircraft carrier like flight deck and island configurations on the burble effect. There are no design guidelines with respect to optimum aircraft carrier flight deck and island configuration. Adverse effect of lack of aerodynamic design guidelines of an aircraft carrier at the Preliminary Design stage are seen only during the trials and testing stage. Any corrective action at this stage, may lead to massive increase in cost and time, and may not be feasible at that stage. The only way for the pilots to cope up with any adverse aerodynamic effects of the aircraft carrier wake would be through increased training to hone their skills.

The motivation for this study is to overcome the lack of design data related to the aerodynamic characteristics of an aircraft carrier, during the preliminary design

stage and come out with design guidelines which could be incorporated during the preliminary design stage of an aircraft carrier design, so as to reduce the burble effect and ease the pilot workload.

As a prelude to the study, the necessity of a benchmark model of a generic aircraft carrier was considered unavoidable, similar to the benchmark model existing in the automobile industry for a generic car, namely the 'Ahmed Body' and for the Frigates and Destroyers in the form of SFS (Simplified Frigate Ship), SFS1 and SFS2, which would be able to simulate the turbulent wake along/behind the carrier similar to a realistic aircraft carrier. An inhouse model of a simplified aircraft carrier in a 1:300 scale, the Generic aircraft carrier (GAC) is developed at IIT Delhi, which is able to simulate the burble effect and turbulence behind similar to a realistic aircraft carrier. Inhouse experiments are conducted using pressure probes to map the pressure field on the flight deck of the GAC with and without the island structure (BGAC configuration) to arrive at the most optimum turbulence model for carrying out CFD studies. The SST k-ω turbulence model was determined to be the most optimum with an error of less than 7% compared to the inhouse experiments for both the GAC and the BGAC variants. To further validate the numerical model, CFD studies are carried out and results compared with the experimental test results of Nimitz and Ford class of island structure published in open source and good qualitative agreement with contours of forward velocity, pitch angle and yaw angles in the transverse plane at a distance of 1/3rd L (L being the length of the aircraft carrier in model scale) behind the aircraft carrier model, is obtained. Good qualitative validation has been obtained using CFD, with the velocity field behind and along the GAC, reported in literature using Particle Image Velocimetry (PIV). The velocity results were made available to me by Mr Vignesh who has completed his PhD thesis (Experimental and computational studies of the flow characteristics over a Generic Aircraft Carrier with and without the island).

Unsteady and Steady RANS computations is carried out using commercial CFD solver Ansys Fluent on GAC and BGAC variants and the validity of using Steady RANS for further parametric studies is established. Mathematical constructs using deficits in the u-velocity, w-velocity and the average Turbulence Kinetic Energy (TKE) has been used to quantitatively ascertain the pilot workload and burble effect along a specified glideslope path using metrics like $u_{Av\_Variation}$, $w_{Av\_Variation}$ and $TKE_{Average}$. A comparative analysis of the airwake around and behind the GAC and the BGAC variants along

different glideslope path is carried out and a quantitative index for the pilot workload is obtained for both the variants. The individual contribution of the island to the total turbulence along various glideslope paths has been ascertained.

Further studies on the BGAC configuration have been carried out by varying various parameters of the flight deck, namely, filleting the notches, rounding/ angled sloping of the flight deck edges and fitment of passive devices on the flight deck. Substantial improvements to the flow field is seen by all the passive modifications to the flight deck configurations. Thereafter studies on the GAC variant is undertaken by varying the geometrical shape of the island structure. The effects of the geometrical features of the island (varying the aspect ratio, length and the geometrical profile shape of the island) and its effect on the turbulence generated behind the aircraft carrier are studied and a set of design guidelines which could aid the naval ship design during the preliminary design stage has been arrived at.

The comprehensive studies undertaken on the various variants of GAC and BGAC models are a first of its type undertaken anywhere and would go a long way in providing design stage inputs to an aircraft carrier designer, for obviating the detrimental effects of flight deck and island configurations on the aerodynamic wake behind the carrier and thus reducing the pilot workload.