EXPERIMENTAL AND COMPUTATIONAL STUDIES OF THE FLOW CHARACTERISTICS OVER A GENERIC AIRCRAFT CARRIER WITH AND WITHOUT THE ISLAND.

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EXPERIMENTAL AND COMPUTATIONAL STUDIES OF THE FLOW CHARACTERISTICS OVER A GENERIC AIRCRAFT CARRIER WITH AND WITHOUT THE ISLAND.

by

K Vignesh Kumar

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Dedicated to Samyuktha and Vittal

CERTIFICATE

This is to certify that the thesis titled "**Experimental and Computational Studies of the Flow Characteristics over a Generic Aircraft Carrier With And Without the Island**", being submitted by **K Vignesh Kumar** is report of bonafide research work carried out by him under our supervision. This thesis has been prepared in conformity with the rules and regulations of Indian Institute of Technology, New Delhi, India. We further certify that the thesis has attained a standard required for a Ph.D. degree of the Institute. The research reported, and results presented in the thesis have not been submitted, in part or full to any other Institute or University for the award of any degree or diploma.

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xx-sd/-xx

(K Vignesh Kumar)

ABSTRACT

Naval aviation is a fascinating and complex field of military operations. Compared to land-based aviation facilities, aircraft operating from ships at sea are burdened with constraints of space and challenging environmental conditions. The epitome of ship borne flight operations is the operation of fighter aircraft from an aircraft carrier, which is a large ship that serves as a full-fledged floating air base, capable of launching and recovering aircraft from its flight deck.

Landing an aircraft on a carrier ranks as one of the most demanding tasks for naval pilots. The limited length of landing runway available, seakeeping motions of the landing platform, high landing speeds required for fighter aircraft etc., make the landing operation a complex evolution. Additionally, the superstructure (island), deck/hull edges and other physical features of the carrier, generate turbulent air wake characterized by regions of large separated flows. In aviation parlance, this zone of disturbed flow is called the 'burble' and is encountered by pilots during their landing approach. These factors impose high workload on the pilot during the critical landing phase and lead to pilot errors, touch-and-go landing attempts (‘bolters’) and cause flight accidents.

The motivation for the present study is to ease pilot workload and thereby reduce carrier landing accidents, by studying and improving flow in the carrier environment. The study focusses on the effect of the island, on the flow in the flight approach zone and investigates sensitivity of the burble to island location.

Due to the classified nature of military data, very less information is available in open domain regarding flow studies on aircraft carriers. Recognizing that there is presently no common benchmark model for aircraft carriers (akin to the internationally accepted Simple Frigate Shape-SFS), a simplified Generic Aircraft Carrier (GAC) model that inherits the salient aerodynamic traits of all actual aircraft carriers in service, is developed as part of the present study. A comprehensive database of experimental data is generated by testing the GAC model in the IIT Delhi Wind Tunnel. Pressure distribution over the deck of the GAC is measured using 105 pressure taps installed at discrete locations covering the entire flight deck.

A novel design concept of raising the island clear off the deck, supported on cylindrical pillars, is proposed as a feasible solution to improve flow in the flight approach zone. Pressure distribution is measured over three variants of GAC (without island, with island and raised island) for comparison of the effect of the island in modifying the flow in each case. In the second phase of experiments, Particle Image Velocimetry is employed to measure velocity and turbulence intensity in the carrier environment, which are identified as the principal contributors to pilot workload from literature. Smoke visualization and tufts are used to undertake extensive flow visualization experiments to obtain corroboratory insights into the flow features.

The experimental domain is modelled numerically in CFD using ANSYS FLUENT and a thorough validation study is undertaken to identify an adequate turbulence model that predicts the flow in the carrier environment with acceptable

accuracy. The validated numerical model (SST k-ω) is engaged to parametrically vary the island location and study the effect on flow in the flight approach zone. Numerical indices relating to pilot workload are specifically formulated in the present study, to qualify the relative merit of different configurations based on statistics of flow parameters measured along flight approach path. Preliminary design guidelines for favourable island position are derived from the parametric investigation, to aid future aircraft carrier concept designs. Scope for future work in the field, is also suggested, to build upon the foundation laid by the present study.

सार

नौसेना विमानन सैन्य अभियानों का एक आकर्षक और जटिल क्षेत्र है। भूमि-आधारित विमानन सुविधाओं की तुलना में, समुद्र में जहाजों से चलने वाले विमान अंतरिक्ष की बाधाओं और अविश्वसनीय पर्यावरणीय परिस्थितियों के बोझ से दबे हुए हैं। जहाज से जन्मे उड़ान संचालन का प्रतीक एक विमान वाहक से लड़ाकू विमान का संचालन है, जो एक बड़ा जहाज है जो एक पूर्ण विकसित अस्थायी हवाई अड्डे के रूप में कार्य करता है, जो अपने उड़ान डेक से विमान को लॉन्च करने और पुनर्प्राप्त करने में सक्षम है।

एक विमानवाहक पोत पर उतरना नौसेना के पायलटों के लिए सबसे अधिक मांग वाले कार्यों में से एक है। लैंडिंग रनवे की सीमित लंबाई उपलब्ध है, लैंडिंग प्लेटफ़ॉर्म की चुपके गति, लड़ाकू विमानों के लिए आवश्यक उच्च लैंडिंग गति आदि, लैंडिंग ऑपरेशन को एक जटिल विकास बनाते हैं। इसके अतिरिक्त, सुपरस्ट्रक्चर (द्वीप), डेक / पतवार किनारों और वाहक की अन्य भौतिक विशेषताएं, बड़े पृथक प्रवाह के क्षेत्रों की विशेषता अशांत हवा जगाती हैं। विमानन क्षेत्र में, अशांत प्रवाह के इस क्षेत्र को 'बर्बल' कहा जाता है और पायलटों द्वारा उनके लैंडिंग दृष्टिकोण के दौरान इसका सामना किया जाता है। ये कारक महत्वपूर्ण लैंडिंग चरण के दौरान पायलट पर उच्च कार्यभार लगाते हैं और पायलट त्रुटियों, टच-एंड-गो लैंडिंग प्रयासों (and बोलर्स) का नेतृत्व करते हैं और उड़ान दुर्घटनाओं का कारण बनते हैं।

वर्तमान अध्ययन की प्रेरणा पायलट कार्यभार को कम करना है और जिससे वाहक वातावरण में प्रवाह में सुधार और सुधार के द्वारा वाहक लैंडिंग दुर्घटनाओं को कम किया जा सकता है। अध्ययन उड़ान के दृष्टिकोण क्षेत्र में प्रवाह पर द्वीप के प्रभाव पर ध्यान केंद्रित करता है और द्वीप स्थान के लिए दफन की संवेदनशीलता की जांच करता है।

सैन्य डेटा की वर्गीकृत प्रकृति के कारण, विमान वाहक पर प्रवाह अध्ययन के संबंध में खुले डोमेन में बहुत कम जानकारी उपलब्ध है।

यह स्वीकार करते हुए कि वर्तमान में विमान वाहक के लिए कोई सामान्य बेंचमार्क मॉडल नहीं है (अंतरराष्ट्रीय स्तर पर स्वीकृत सरलीकृत शिप-एसएफएस के समान), एक सरलीकृत जेनेरिक एयरक्राफ्ट कैरियर (जीएसी) मॉडल है जो सेवा में सभी वास्तविक विमान वाहकों के मुख्य वायुगतिकीय लक्षणों को विरासत में मिला है। वर्तमान अध्ययन के भाग के रूप में। IIT दिल्ली विंड टनल में GAC मॉडल का परीक्षण करके प्रायोगिक डेटा का एक व्यापक डेटाबेस तैयार किया गया है। जीएसी के डेक पर दबाव वितरण को पूरे उड़ान डेक को कवर करने वाले असतत स्थानों पर स्थापित 105 दबाव नल का उपयोग करके मापा जाता है।

डेक से दूर द्वीप को साफ करने की एक उपन्यास डिजाइन अवधारणा, बेलनाकार खंभों पर समर्थित, उड़ान दृष्टिकोण क्षेत्र में प्रवाह को बेहतर बनाने के लिए एक संभव समाधान के रूप में प्रस्तावित है। प्रत्येक मामले में प्रवाह को संशोधित करने में द्वीप के प्रभाव की तुलना के लिए दबाव वितरण को जीएसी (द्वीप के साथ द्वीप और उठाए गए द्वीप के बिना) के तीन वेरिएंट पर मापा जाता है। प्रयोगों के दूसरे चरण में, वाहक वातावरण में वेग और अशांति की तीव्रता को मापने के लिए कण छवि वेलोसिमिट्री को नियोजित किया जाता है, जिसे साहित्य से पायलट कार्यभार के प्रमुख योगदानकर्ताओं के रूप में पहचाना जाता है। धुआँ दृश्य और टफट्स का उपयोग प्रवाह की विशेषताओं में कोरोबेरेटरी अंतर्दृष्टि प्राप्त करने के लिए व्यापक प्रवाह विज़ुअलाइज़ेशन प्रयोगों को करने के लिए किया जाता है।

प्रयोगात्मक डोमेन ANSYS FLUENT का उपयोग करते हुए सीएफडी में संख्यात्मक रूप से मॉडलिंग की जाती है और स्वीकार्य सटीकता के साथ वाहक वातावरण में प्रवाह की भविष्यवाणी करने वाले एक पर्याप्त अशांति मॉडल की पहचान करने के लिए गहन सत्यापन अध्ययन किया जाता है। मान्य संख्यात्मक मॉडल (SST k-ω) पैरामीट्रिक से जुड़ा हुआ है जो द्वीप के स्थान को बदलता है और उड़ान दृष्टिकोण क्षेत्र में प्रवाह पर प्रभाव का अध्ययन करता है। प्रायोगिक कार्यभार से संबंधित संख्यात्मक सूचकांक विशेष रूप से वर्तमान अध्ययन में तैयार किए गए हैं, जो फ्लाइट एप्रोच पथ के साथ मापा जाने वाले प्रवाह मापदंडों के आंकड़ों के आधार पर विभिन्न विन्यासों के सापेक्ष योग्यता को योग्य बनाते हैं। अनुकूल द्वीप स्थिति के लिए प्रारंभिक डिजाइन दिशानिर्देश पैरामीट्रिक जांच से प्राप्त होते हैं, भविष्य के विमान वाहक अवधारणा डिजाइनों की सहायता के लिए। वर्तमान अध्ययन द्वारा निर्धारित नींव पर निर्माण करने के लिए, क्षेत्र में भविष्य के काम के लिए स्कोप भी सुझाया गया है।

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NOMENCLATURE

Notation

b	Island Block Breadth, *cm.*
f	Freeboard (Depth–Draught), *cm.*
k	Turbulent Kinetic Energy, m^2/s^2
l	Island Block Length, *cm.*
r_u	Lever of Disturbance for *u, m.*
u_m	Local mean velocity in streamwise direction, *m/s.*
urms	Root mean square of u velocity, *m/s.*
v_m	Local mean velocity in transverse direction, *m/s.*
vrms	Root mean square of u velocity, *m/s.*
u/V_∞	Normalised velocity component in x direction
w/V_∞	Normalised velocity component in z direction
x_s	Longitudinal Position of Island (from Aft edge), *m.*
y_s	Starboard edge of island to ship starboard, *m*.
B	Breadth of GAC Model (Maximum at Flight Deck),*cm.*
D	Depth of Aircraft Carrier, *m*.
H	Height of Island Block of GAC Model, *m*.
L	Length of GAC Model (Maximum at Flight Deck), *m*.
Port	Port Side of Ship (Left)
Starboard	Starboard Side of Ship (Right)
T	Draught of Aircraft carrier, *m*.
U	Velocity component in x direction *m/s.*
V	Velocity component in y direction *m/s.*
V_∞	Free Stream Velocity *m/s.*
V_{ship}	Velocity vector of ship *m/s.*
V_{wind}	Velocity vector of Wind *m/s.*
V_w	I V_{wod} I, Free stream velocity in wind tunnel, *m/s.*
V_{wod}	Wind Over Deck Velocity, *m/s.*
W	Vertical Component of velocity (in z direction), *m/s.*

X	Distance Along Longitudinal Direction X Axis, *m.*
Y	Distance Along Transverse direction, *m*.
Z	Distance Along Vertical Direction, *m.*
ε	Turbulent dissipation rate, m^2/s^3
μ_t	Turbulent viscosity, m^2/s.
ρ	Density of Air, kg/m^3 .
ψ	Rotation angle of Island about vertical axis, *degree.*
ω	Specific dissipation rate, */s.*

Acronyms

CAC	Carrier Approach Criteria
CATOBAR	Catapult Assisted Take-Off Arrested Recovery
CBG	Carrier Battle Group
DES	Detached Eddy Simulation
DNS	Direct Numerical Simulation
GAC	Generic Aircraft Carrier
LDV	Laser Doppler Velocimetry
LES	Large Eddy Simulation
LHA	Landing Helicopter Assault Ship
LPD	Landing Platform Dock Ship
PIV	Particle Image Velocimetry
RANS	Reynolds Averaged Navier Stokes Equations
RSM	Reynolds Stress Model
SFS	Simple Frigate Shape
STOBAR	Short Take-Off Arrested Recovery
TI	Turbulence Intensity
TKE	Turbulent Kinetic Energy
TTCP	The Technical Cooperation Program
VTOL	Vertical Take-off and Landing
WOD	Wind Over Deck