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INTA

EXPERIMENTAL ANALYSIS OF THE FRIGATE EXHAUST IMPACT ON HELICOPTER OPERATIONS OVER THE FLIGHT DECK

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CONTENT

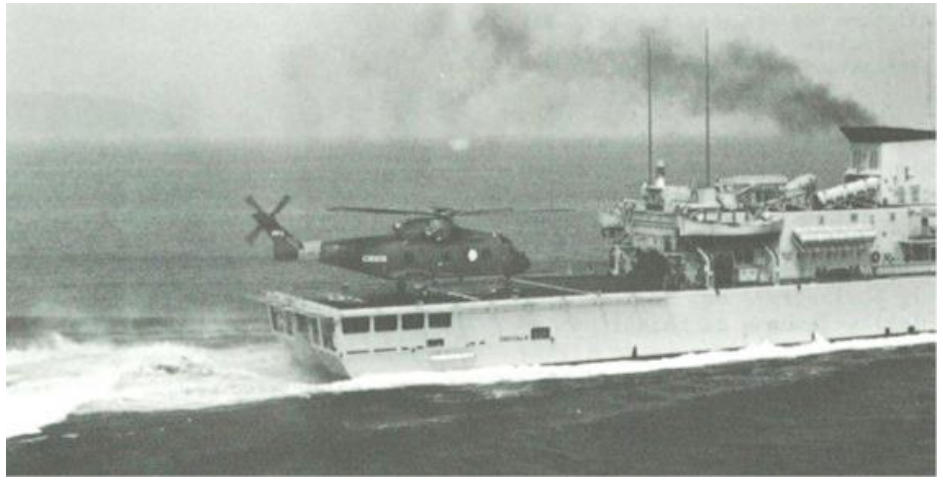
1. INTRODUCTION

Military ships possess the necessary infrastructure to facilitate helicopter operations on board:

- ❑ Landing and take-off on the flight deck
- ❑ Refuelling either on the flight deck or within the hangar

1. INTRODUCTION

Smoke dispersion problem



Sensitive areas

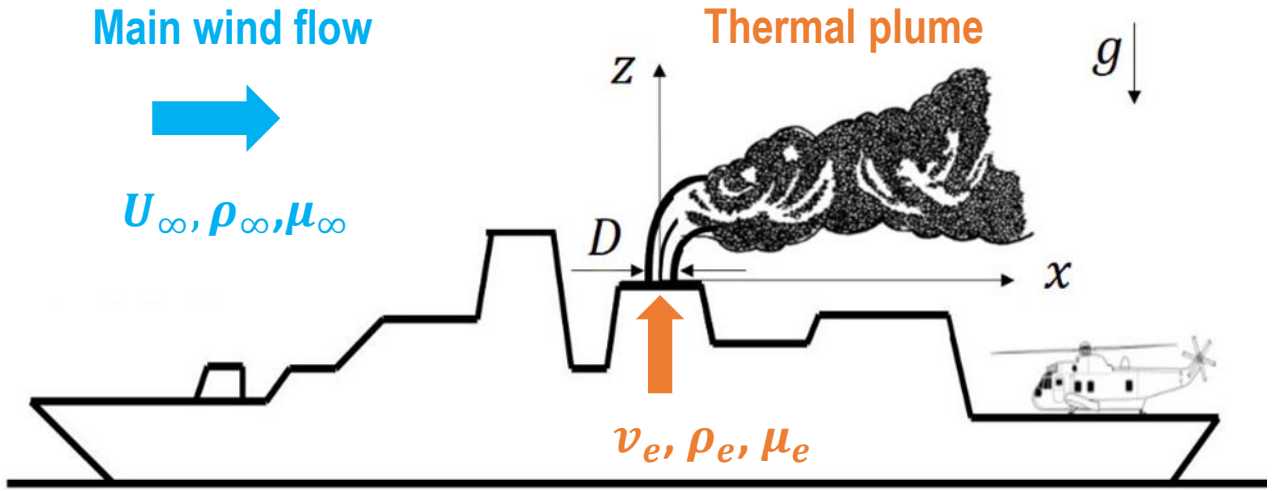
- Flight deck.
- Communication antennae.
- Radars.
- Weapons systems.
- Command deck.

❑ **Elimination of the emissions to ENSURE the SAFETY of HELICOPTER MANEUVERS !**

INTA's Capabilities → **Wind tunnel tests** → **Experimental data** → **Critical regions**

CONTENT

2. SMOKE DISPERSION PROBLEM



V_x: velocity of the flow $(x = \infty, e)$.
ρ_x: density of the flow $(x = \infty, e)$.
μ_x: dynamic viscosity of the flow $(x = \infty, e)$.
D: funnel diameter.
A: reference area.
g: gravity.

WIND TUNNEL TESTS

Dynamic similarity between scaled-model and real ship.

Parameters involved in the smoke dispersion problem:

- Momentum ratio between the main wind flow and the exhaust flow:

$$J = \frac{\rho_\infty U_\infty^2}{\rho_e v_e^2}$$

- Mass flow ratio between the main wind flow and the exhaust flow:

$$R_{FM} = \frac{\rho_e v_e D^2}{\rho_\infty U_\infty A}$$

- Buoyancy of the thermal plume:

$$R_{FP} = \frac{\Delta \rho g D}{\rho_\infty U_\infty^2}$$

- Reynolds number:

$$Re = \frac{\rho_\infty U_\infty A}{\mu_\infty} > 10^5 \text{(critical } Re\text{)}$$

CONTENT

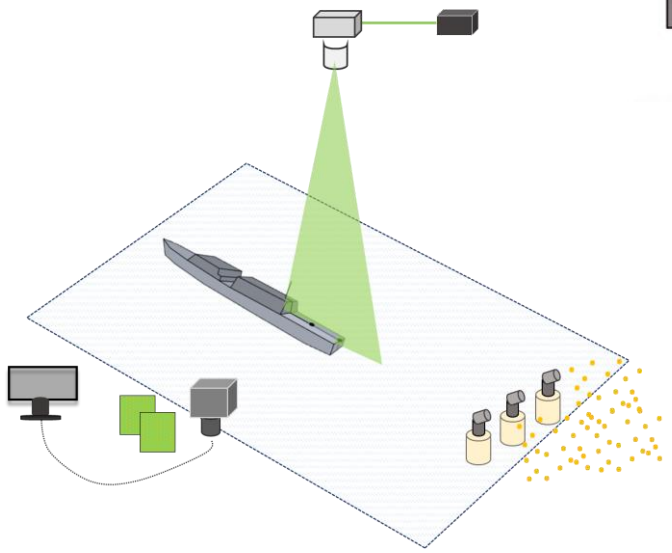
3. INTA'S CAPABILITIES

❑ Smoke visualization

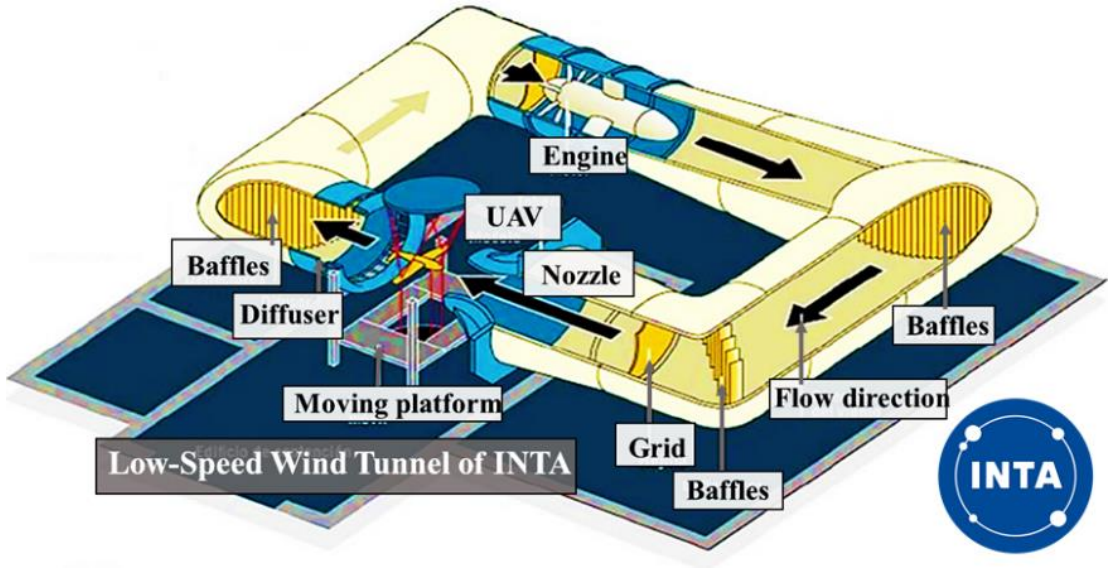
- By injecting smoke through the chimneys.
- Direct observation of the flow (photographs or video recording).

❑ PIV visualization

- Advanced experimental technique for flow velocity measurement (laser plane).
- No direct flow observation.
- Flow velocity contourns (processing task).



❑ Nº1 Low-Speed Wind Tunnel INTA



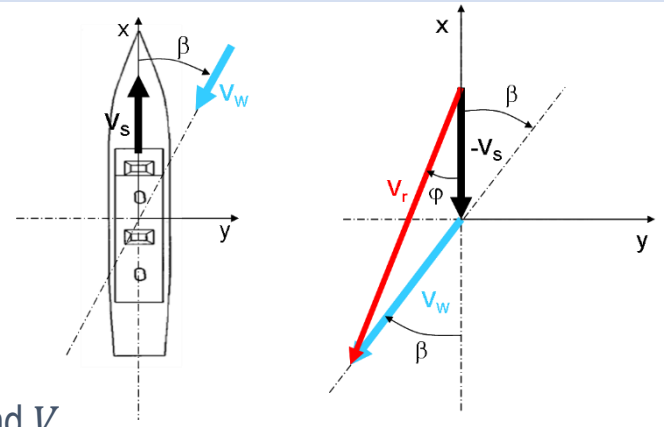
- Closed circuit.
- Elliptical test section 3 x 2 m^2.
- Maximum velocity 60 m/s.
- Turbulence intensity $< 0.5\ \%$.

CONTENT

4. SMOKE VISUALIZATION TECHNIQUE

➢ **Smoke injection:**
(Rosco Fog Machine 1900 model)

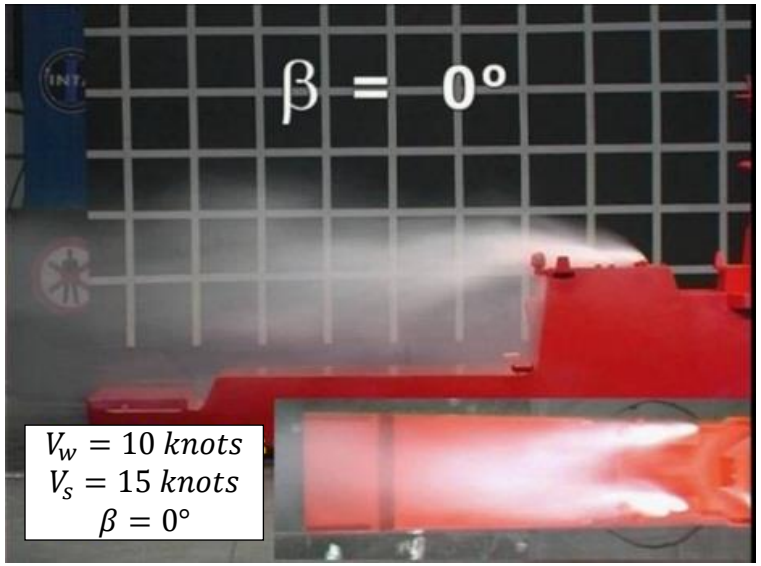
4. SMOKE VISUALIZATION TECHNIQUE

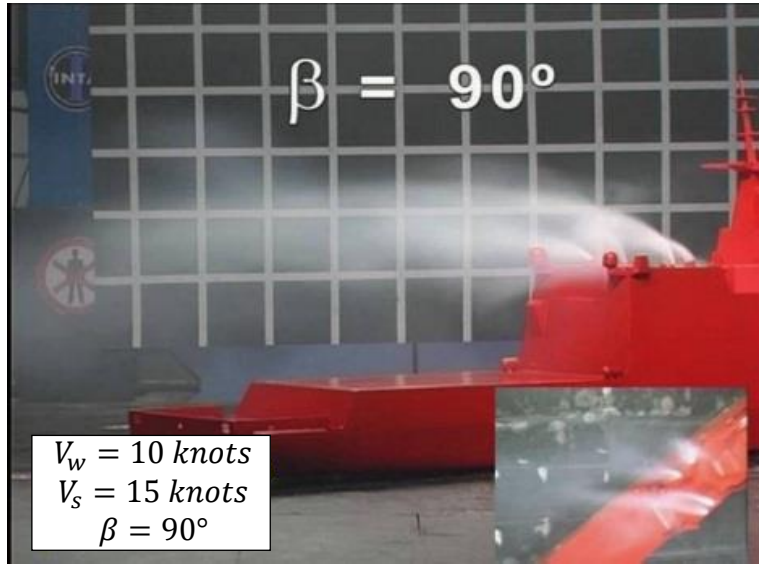


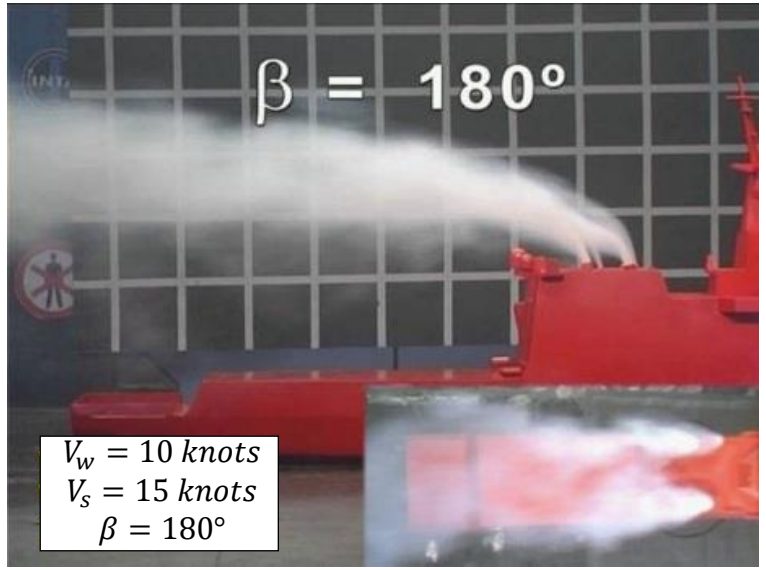
❑ Commercial tests:

Scaled frigate model (1:50) built in wood and painted in red.

V_s: Vessel velocity. V_w: Wind velocity. β: Angle between V_s and V_w. V_r: Relative wind velocity. φ: Angle between V_r and V_s.



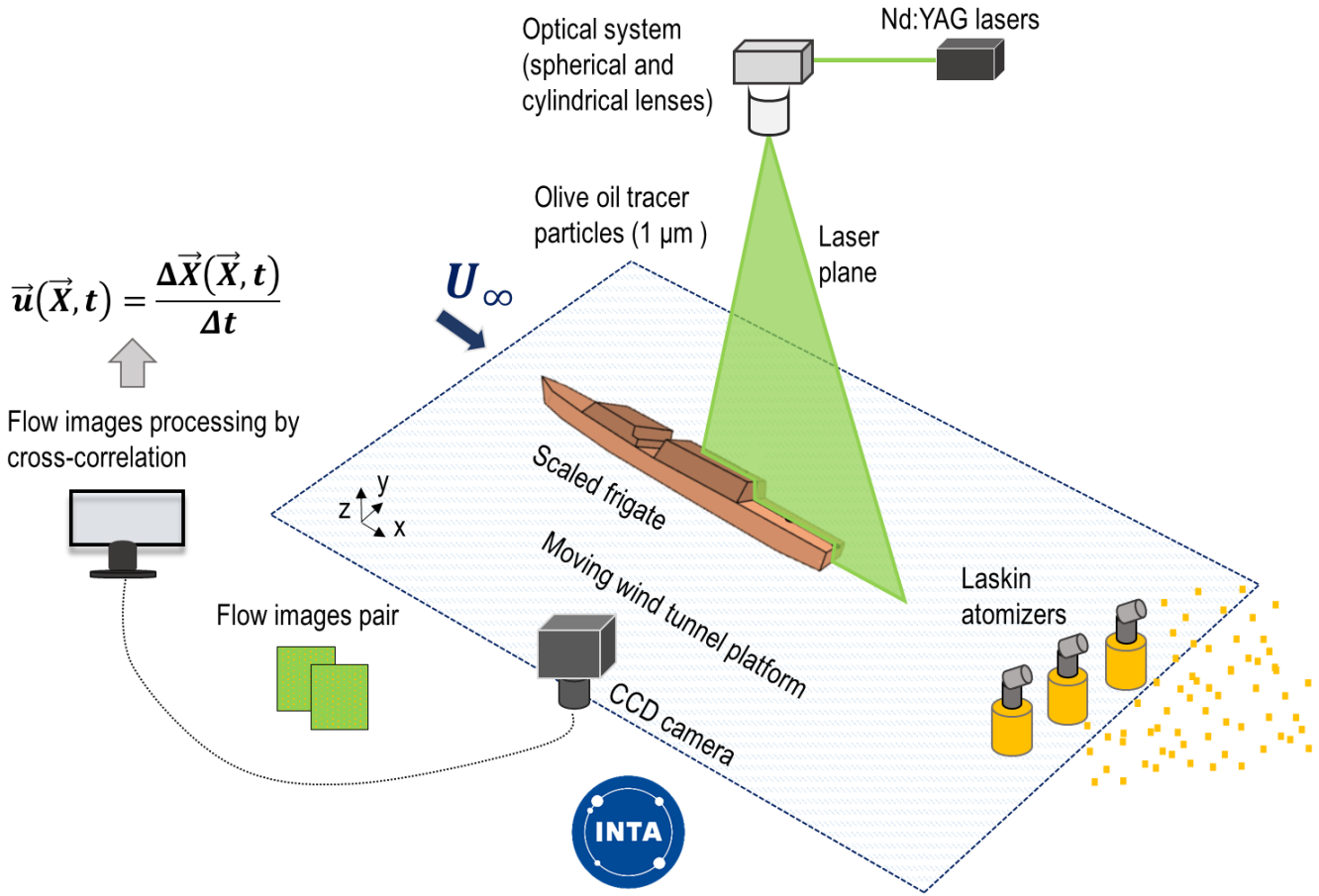




$Re = 1.5 \cdot 10^6 > 10^5$(critical Re for blunt bodies) ✔

CONTENT

5. PARTICLE IMAGE VELOCIMETRY (PIV) TECHNIQUE



PIV characteristics

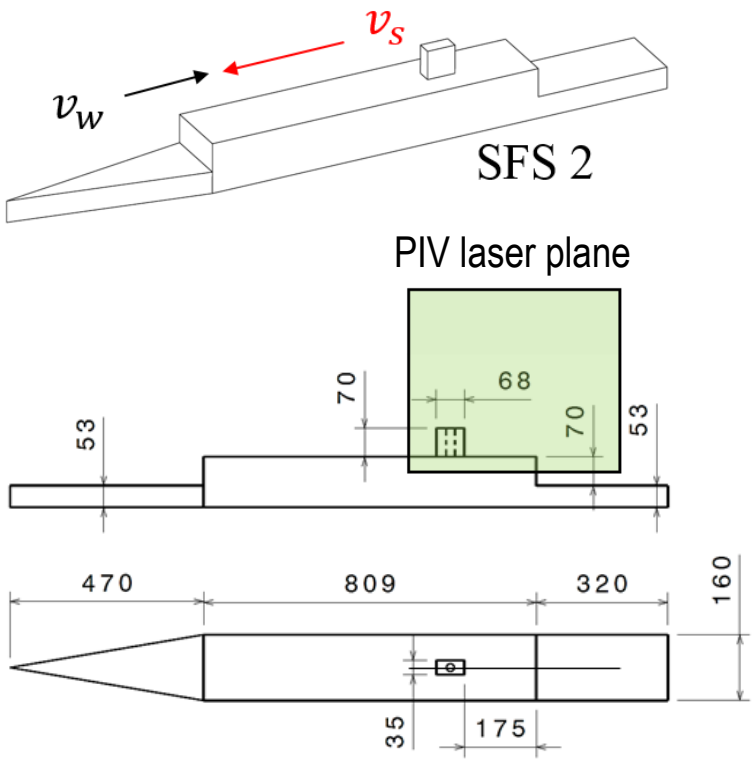
- Olive oil tracer particles of 1 μm.
- Two Neodymium-doped Yttrium Aluminium Garnet (Nd:YAG) lasers.
- Time interval of 25 μs.
- Laser pulse energy of 190 mJ.
- 100 pairs of flow images.

CONTENT

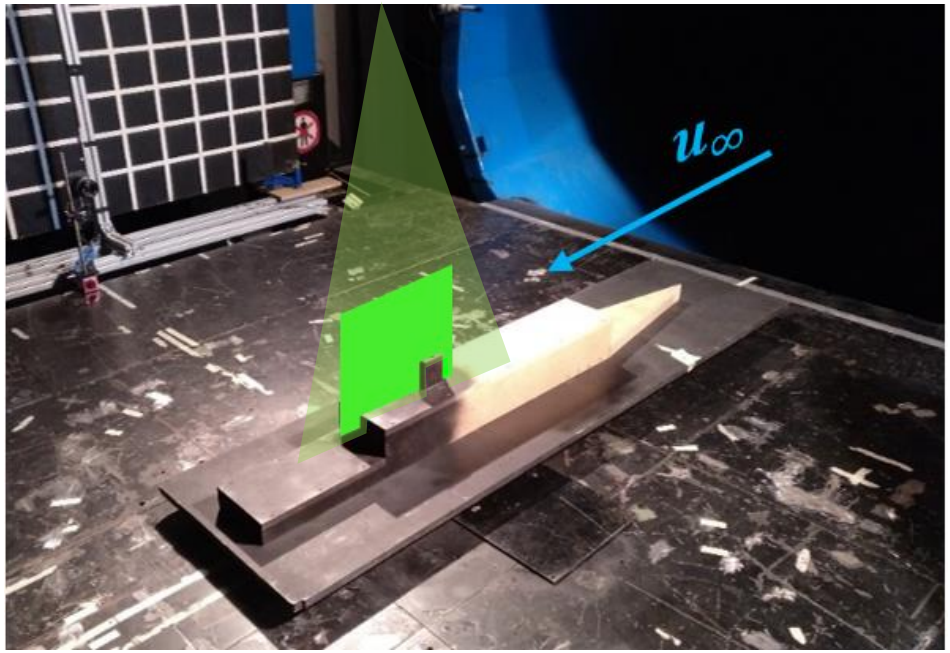
6. EXPERIMENTAL TESTS USING PIV TECHNIQUE

❑ Research tests:

Simplified Frigate Shape (SFS2) (1:85), made of wood and painted in black.



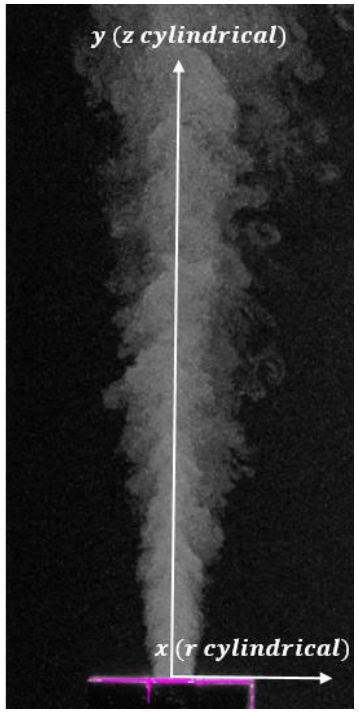
Experimental set-up in the Nº1 wind tunnel of INTA



$Re = 1.1 \cdot 10^5 > 10^5$(critical Re for blunt bodies) ✔

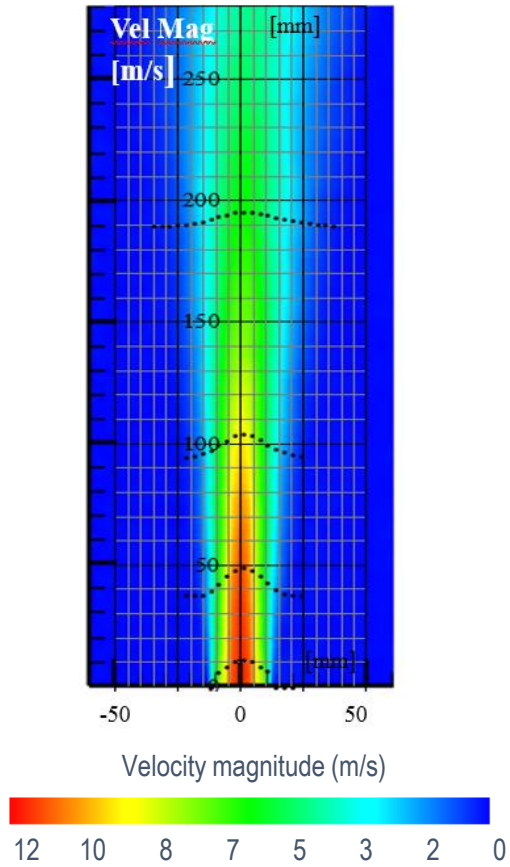
6. EXPERIMENTAL TESTS USING PIV TECHNIQUE

PIV instantaneous image

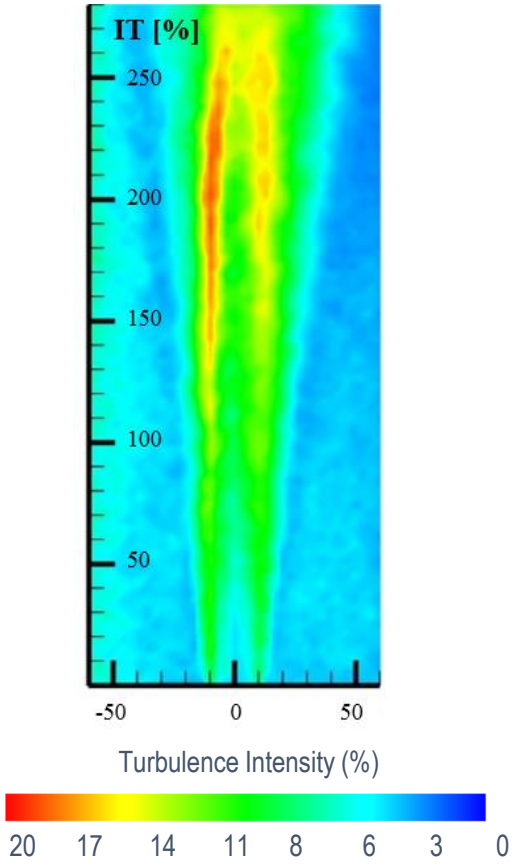


Isolated jet: No wind tunnel velocity .

PIV Velocity map



PIV Turbulence map

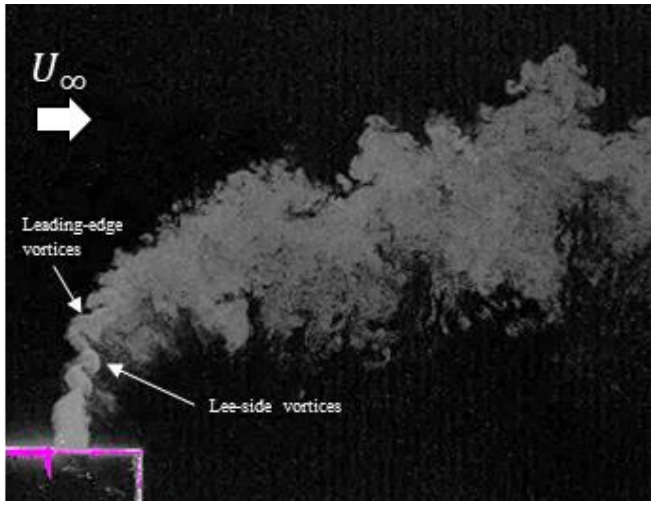


$$IT\ [\%] = \frac{\sigma}{u_\infty} \cdot 100 = \frac{\sqrt{{\sigma_u}^2 + {\sigma_w}^2}}{u_\infty} \cdot 100$$

- IT :Turbulence Intensity.
- σ_u: horizontal velocity fluctuation.
- σ_v: vertical velocity fluctuation

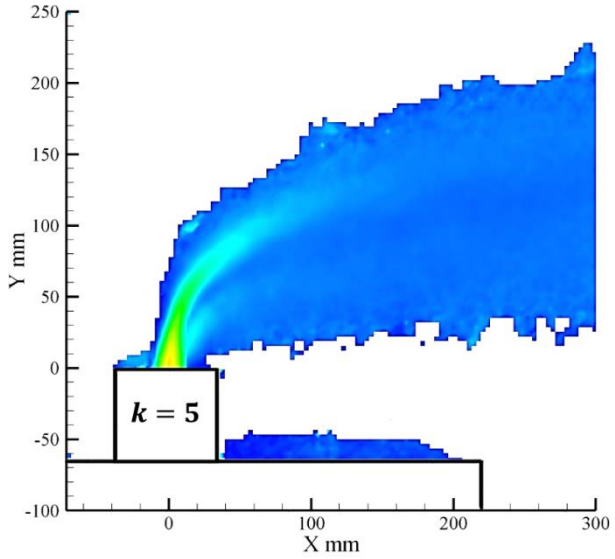
6. EXPERIMENTAL TESTS USING PIV TECHNIQUE

PIV instantaneous image



Cross flow: Wind tunnel velocity.
Olive oil tracer particles through the chimney.

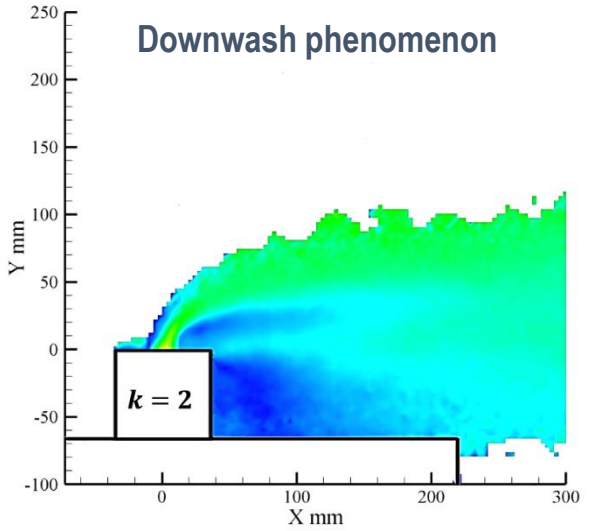
PIV Velocity map



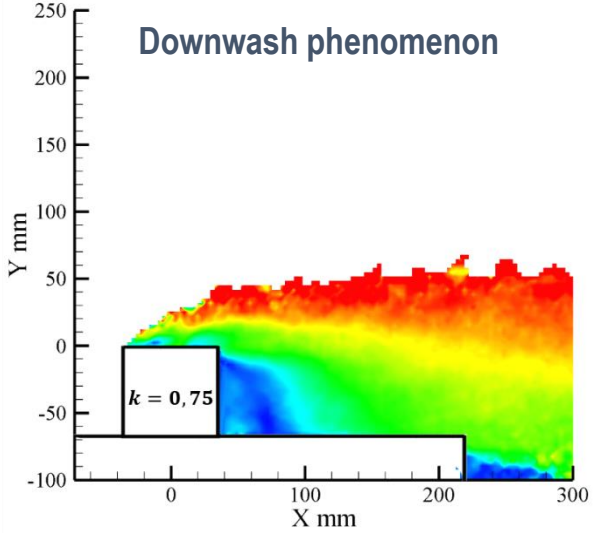
$$k = V_{jet}/U_\infty$$

k: Velocity ratio
V_{jet}: Jet velocity (10 m/s)
$U_\infty = 2$ m/s

Downwash phenomenon

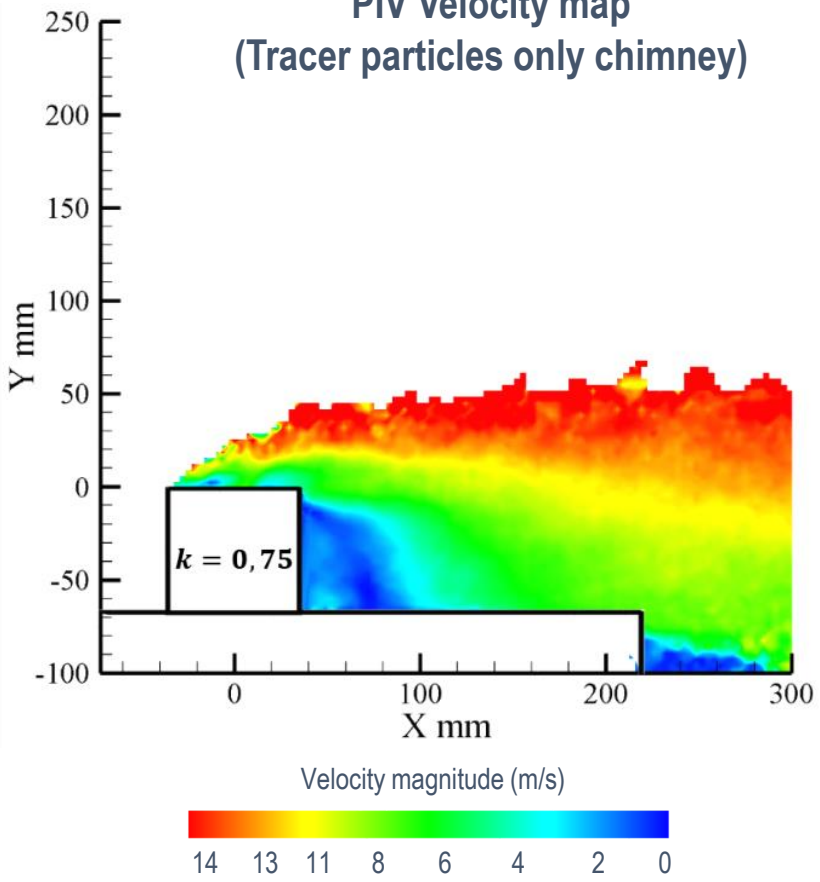


Downwash phenomenon

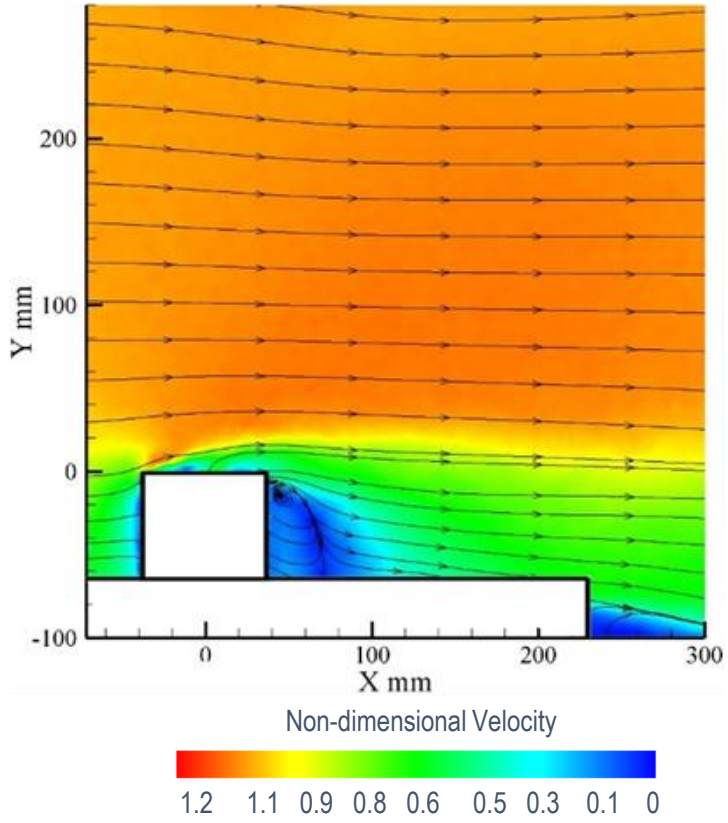


6. EXPERIMENTAL TESTS USING PIV TECHNIQUE

PIV Velocity map
(Tracer particles only chimney)



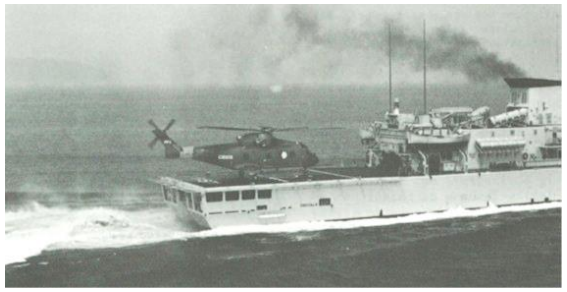
PIV Velocity map



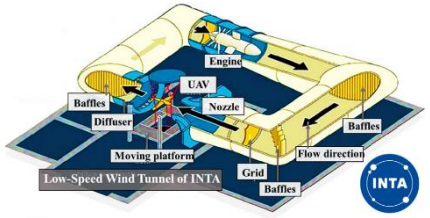
CONTENT

7. CONCLUSIONS

FLIGHT DECK where helicopter operations take place, the ACCUMULATION of EXHAUST GASES can interfere with them.



Elimination of exhaust gases: SAFETY of helicopter maneuvers. ✔



➢ **Experimental tests in the WIND TUNNEL to collect experimental data of the most critical regions.**

Smoke visualization

Photographs or video: degree of visibility loss.

PIV technique

Instantaneous flow images, velocity and turbulence intensity maps.

INTA'S CAPABILITIES to effectively address the SMOKE DISPERSION PROBLEM on frigates.

THANK YOU FOR YOUR ATTENTION