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EXPERIMENTAL TECHNIQUES IN THE WIND TUNNEL OF NAVAL ARCHITECTURE FACULTY

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ABSTRACT

The implementation of innovative solutions in the field of shipbuilding requires the continuous development of research infrastructure. The hydro-aerodynamic problems of fluid flow around the hulls can be solved with numerical and/or experimental techniques. In any case, the validation of the numerical solutions is performed in specialized hydro-aerodynamic laboratories by means of the experimental model tests. In this context, a wind tunnel was developed at the Naval Architecture Faculty of “Dunarea de Jos” University of Galati, in order to measure the aerodynamic forces and moments or the speed and pressure distribution on the hull, generated by the wind action. This paper presents the most important types of problems that can be experimentally approached in the aerodynamic tunnel and the specific experimental equipments. The wind tunnel development was financed from the university funds.

Keywords: wind tunnel, experimental equipment, aerodynamic problems.

1. INTRODUCTION

The study of the complex hydro-aerodynamic problems generated by the fluid flow around ship hull or typical naval profiles require an adequate research infrastructure, both theoretically and experimentally.

The CFD methods and experimental model tests in specialized hydro-aerodynamic laboratories represent common techniques today, for solving conceptual ship design problems and implementation of innovative solutions. Although the use of CFD techniques has definite advantages, experimental validation is still necessary.

The Research Center of the Naval Architecture Faculty of “Dunarea de Jos” University of Galati has been established since 2001 and is equipped with the appropriate infrastructure, for solving both ship hydro-aerodynamics and structurals problems, on the basis of CFD, FEM and experimental model techniques.

The numerical results of the hydro-aerodynamics problems are validated by means of the experimental model tests in Towing Tank, Cavitation Tunnel and/or Wind Tunnel. The activity of the Research Center of the Naval Architecture Faculty is known at international level ([1], [2], [3], [4]).

Within the operational reinforcement program of the experimental research infrastructure, supported by the university, a ship aerodynamic tunnel was developed in the last years.

A wind tunnel (Figure 1) and specific experimental equipments with a good level of measurement accuracy were purchased.

The development of necessary experimental methodologies to study the aerodynamic problems created by the fluid flow around the ship hull or naval profiles was the main objective of this project. The most important problems that can be solved on the basis of wind tunnel experimental methodologies are:

- Measurement of the aerodynamic forces and moments generated by the wind action, using a six-components transducer;
- Measurement of the wind pressure distribution on the profiles surface (rudders, stabilised fins), using a pressure scanner with 16 channels;
- Measurement of the instantaneous wind velocity, using a MiniCTA-system;
- Measurement of the wind pressure in the tunnel, using Pitot tubes and a crossing rail automatic system;
- Visualization of the flow streamlines and smoke dispersion.

The main dimensions of the wind tunnel are: length=17 m, width=3.7 m and height=3.4 m. Also, the main dimensions of the measuring section of the tunnel (presented in Figure 2) are: length=2.5 m, width=0.82 m and height=0.58 m.

The maximum air velocity of 23.5 m/s can be obtained and the maximum physical model length of 2 m can be used in the wind tunnel.

The wind tunnel drive system includes an axial flow blower with variable speed and a motor power of 55 kW and 1450 RPM.

The measuring equipments and experimental data acquisition and processing system were provided by BP Install Services company, from Bucharest.

2. MEASURING EQUIPMENTS

The six-components transducer (presented in Figure 3) is a complex equipment used to measure the aerodynamic forces and moments developed on a physical model by the wind action in the aerodynamic tunnel. The longitudinal, lateral and vertical forces, as well as the roll, pitch and yaw moments can be measured and the specific aerodynamic coefficients can be calculated.

The six-components transducer has a parallelepipedic structure made of extruded aluminium alloy profiles. Six force dynamometers with a nominal load of 250 N are integrated on the structure lines, in order to determine the six components of the aerodynamic torsor.

Fig. 1. Wind tunnel

Fig. 2. Measuring section

The evaluation of the calibration constants as well as of the six-components interdependence matrix represents a complex procedure, necessary to be performed before the experimental tests.

The acquisition and processing system of the experimental data is based on the National Instruments infrastructure and a dedicated application software.

The pressure scanner with 16 channels (Figure 4) can be used to measure the local differential pressure on the physical model surface, installed in the wind tunnel.

The pressure scanner includes 16 differential pressure transducers (having a measuring range between 0-1000 Pa) which can be individually connected to the pressure sockets, on the physical model surface.

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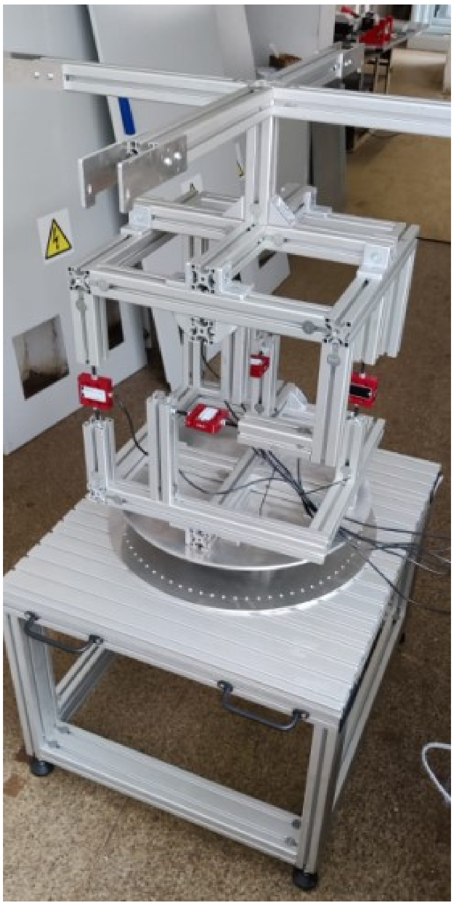

Fig. 3. Six-components transducer

The acquisition and processing system of the experimental data (Figure 5) can be used on the basis of a specific application software.

Fig. 4. Pressure scanner

Typical *NACA rudder profiles* are used as physical models, in order to measure the pressure distribution, on eight measuring points of each side of the profile, located at half of the rudder height (Figure 6).

Fig. 5. Experimental data acquisition of the pressure scanner

Fig. 6. NACA rudder profile

The MiniCTA-system (Constant Temperature Anemometry) produced by Dantec Dynamics (Figure 7) can be used, both with hot-wire and hot-film probes, in order to measure the instantaneous wind velocity and to investigate the aerodynamic flow around the physical model, placed in a wind tunnel.

Measuring of the wind pressure in the tunnel, using *Pitot tubes* and a *crossing rail automatic system* can be performed.

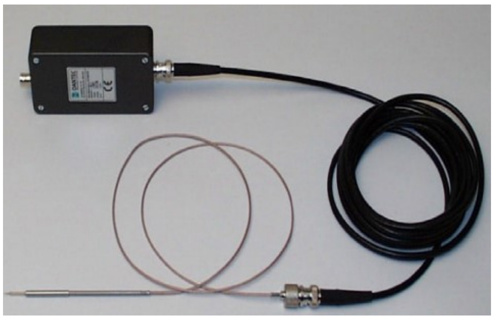

Fig. 7. MiniCTA-system of Dantec Dynamics

The crossing system (Figure 8) includes a crossing rail with mobile carriage, being operated by means of a dedicated drive software (Figure 9).

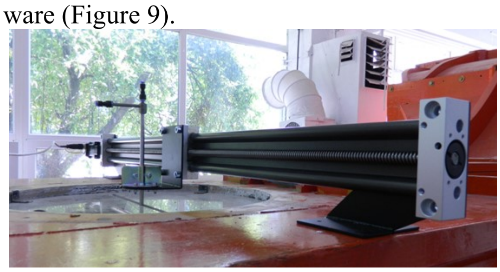

Fig. 8. Crossing rail system

Fig. 9. Drive software of the crossing rail system

Using the crossing rail system, a Pitot tube can be positioned in the established section of the wind tunnel (Figure 10), in order to measure the local dynamic pressure and to calculate the local wind velocity.

Visualization of the smoke dispersion can be performed in the wind tunnel, by using a *smoke generator* (Figure 11) with small dimensions (length=25 cm, width=5.3 cm and height=5.5 cm).

Due to the control mechanism, the battery supplies energy only when necessary. As a consequence, the smoke time is increased. An experimental test with smoke dispersion is present in Figure 12.

Fig. 10. Pitot tube

Fig. 11. Smoke generator

Fig. 12. Smoke dispersion

3. EXPERIMENTAL TESTS ON THE WIND VELOCITY IN THE MEASURING SECTION

The influence of the tunnel side walls on the aerodynamic flow must be minimal. The wind velocity in the measuring section must be relative constant at a preestablished speed of the axial flow blower.

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The flow uniformity in the transversal network nodes of the tunnel measuring section (presented in Figure 13) was investigated, at different blower speeds.

A network step of 50 mm both on **y** transverse axis and **z** vertical axis was established.

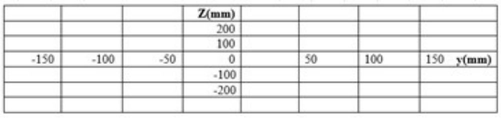

Fig. 13. Network nodes

In order to determine the wind velocity, an experimental system including the Pitot tube (mounted on the crossing rail with mobile carriage) and the pressure scanner was used.

On the basis of the medium dynamic pressure **p**, measured with Pitot tube and pressure scanner, the wind velocity **v** was calculated by means of the relation

$$v = \sqrt{\frac{2 \cdot p}{\rho}} \tag{1}$$

where **ρ** is the air density.

A diagram of the medium dynamic pressure measured in the network nodes is exemplified in Figure 14, in the case of a blower speed equal with 850 RPM.

Also, a similar diagram of the wind velocity is presented in Figure 15. A maximum wind velocity variation of about 1.5% was evaluated in this case.

Similar diagrams should be extended to the full domain of the axial blower speeds and the entire length of the tunnel measurement section.

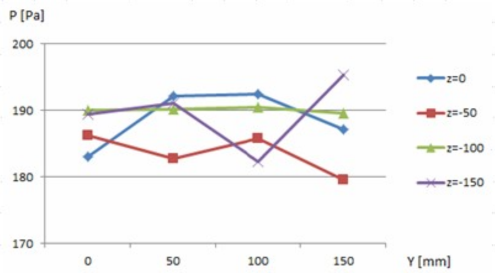

Fig. 14. Wind pressure distribution

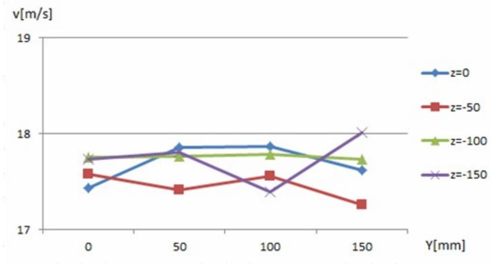

Fig. 15. Wind velocity distribution

The values of the medium dynamic pressures and wind velocities depending by the axial blower speed are presented in Table 1, for the reference point of the middle measuring section, having the coordinates y=z=0.

Table 1. Wind pressure and velocity

Blower Speed n [RPM]	Wind pressure p [Pa]	Wind velocity v [m/s]
100	45.36	8.67
200	60.44	10.01
300	72.65	10.98
400	88.01	12.08
500	107.60	13.36
600	130.20	14.70
700	148.61	15.70
800	173.96	16.99
900	200.52	18.24
1000	225.99	19.36

A wind velocity of 19.36 m/s was obtained in the case of a blower speed equal with 1000 RPM.

4. CONCLUDING REMARKS

Within the operational reinforcement program of the experimental research infrastructure, funded by the "Dunarea de Jos" University of Galati, a wind tunnel was developed in the last years.

The main objective of this project was to perform the specific experimental methodologies, in order to study the aerodynamic problems generated by the fluid flow around the ship hull or distinct profiles.

The measurement of the aerodynamic forces and moments generated by the wind action on the ship models, or of the pressure distribution on the profiles surface, as well as the wind velocity determination and the visualization of the flow streamlines and smoke dispersion represent the most important problems taken into consideration.

As a consequence, a specific experimental research infrastructure was purchased, including the six-components transducer, a scanner pressure with 16 channels, the MiniCTA system, the Pitot tubes set, a smoke generator and the crossing rail automatic system.

Together with the Towing Tank and the Cavitation Tunnel, the Wind Tunnel completes the experimental ship research infrastructure of "Dunarea de Jos" University of Galati. In fact, since last year, our university has become a member of the prestigious international organization ITTC.

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REFERENCES

[1]. **Lungu, A.,** *"Numerical Simulation of the Resistance and Self-Propulsion Model Tests"*, Transactions of ASME, Journal of Offshore Mechanics and Arctic Engineering 142(2): 021905, 2020.

[2]. **Lungu, A.,** *"Unsteady Numerical Simulation of the Behavior of a Ship Moving in Head Sea"*, Paper OMAE2019-95239, ASME. International Conference on Offshore Mechanics and Arctic Engineering, Volume 2: CFD and FSI, 2019.

[3]. **Obreja, C.D., Nabergoj, R., Crudu, L., Domnisoru, L.**, *"Seakeeping Performance of a Mediterranean Fishing Veseel"*, IMAM Conference (International Maritime Association of the Mediterranean), Lisboa, Portugal, ISBN 978-0-8153-7993-5, pp. 483-491, 2017.

[4]. **Obreja, C.D., Nabergoj, R., Crudu, L., Pacuraru, S.**, *"Identification of Hydrodynamic Coefficients for Manoeuvring Simulation Model of a Fishing Vessel"*, Ocean Engineering, Vol. 37, Iss. 8-9, ISSN 0029-8018, pp. 678-687, 2010.

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