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**Test method for distributed friction force measurement in air
layer drag reduction models**

气层减阻分布式阻力测量模型试验方法

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2 Normative references

This document has no normative references.

The symbols given in Table 1 are applicable to this document.

5 Experimental Equipment and Instruments

5.1 Variable Pressure and Variable Speed Circulating Water Tank Circulating water tanks used for measuring the gas layer distribution resistance at a model scale of 10m or more should meet the following requirements.

- a) The test section is over 10m long;
- b) Width and height both exceeding 1m;
- c) The maximum water velocity must not exceed 10 m/s;
- d) Maximum pressure adjustment exceeds 300 kPa.

5.2 Testing Instruments and Meters

5.2.1 Distributed Local Resistance Measurement Sensor The sensor (balance) arrangement and range selection for distributed local resistance measurement are as follows: The location for measuring local resistance distribution should be determined based

on the principal dimensions of the ship or flat plate model used in the experiment, and the estimated cavitation length of the air layer to be formed. Within the cavitation range, select at least three different resistance measurement locations along the longitudinal section (the number of local resistance measurements can be used to divide the longitudinal section of the cavitation into equal parts). Arrangement using section lines. The range of the local resistance measurement sensor should be determined based on the resolution and accuracy characteristics of the strain sensor, and in conjunction with the maximum test flow rate (e.g.,...). 7 m/s (normal sailing speed of large oil and bulk carriers), select a suitable size local resistance measurement unit force plate (e.g., 300 mm x 100 mm). (Using a 300mm x 10mm aluminum plate), estimate the range of resistance that can be measured on the lower surface of the force measuring plate in each unit. (Lower surface of each unit force measuring plate) The magnitude of the resistance is determined by the frictional resistance coefficient, the maximum test flow velocity, and the area of the wetted surface (the surface in contact with the fluid) on the lower surface. (Each unit) The frictional resistance coefficient of the force-measuring plate is based on the experimental Reynolds number (calculated using the distance from the jet nozzle to the center of the force-measuring plate of each local unit as the Reynolds number). The characteristic length, calculated by referring to relevant parameters in conjunction with the water temperature t_w , air temperature t_a , and water density ρ during the experiment, is estimated using the Haisang formula. (1) Calculate.

5.2.2 Atmosphere Condition Observation Camera Equipment

5.2.2.1 The imaging equipment (conventional CCD) used for atmospheric state observation operates normally under continuous lighting conditions, with a pixel count better than 1024x 1024, record at least 25 frames per second.

5.2.2.2 Camera equipment (high-speed cameras) used for observing the dynamic characteristics of air layers can also operate normally under continuous light, and its highest capture speed... The shooting frequency should be no less than 2000 frames per second, and the minimum image quality should be no less than 300,000 pixels.

5.2.3 Piezoelectric Miniature Pulsating Pressure Sensor Pressure sensors used for measuring pulsating pressure on flat surfaces and gas layer surfaces should meet the following requirements.

- a) The outer diameter is no more than 10mm;
- b) The maximum diameter of the pressure-sensitive diaphragm is no more than 6 mm;
- c) The measured frequency response range is greater than 20kHz;
- d) Resolution up to Pa level (piezoelectric sensor), static pressure overload capacity greater than 200 kPa.

5.2.4 DC Amplifier A DC amplifier used for DC signal amplification in resistance measurement has a maximum amplification factor of not less than 1000 times and an accuracy of not more than [missing value]. 0.1%, with multiple selectable levels. The DC amplifier should also provide the maximum external drive power, with multiple selectable levels and low-pass filtering. Function.

5.2.5 Charge Amplifier

5.2.5.1 Charge amplifiers used for amplifying charge signals shall meet the following requirements.

- a) Gain not less than 10mV/pc;
- b) Accuracy not greater than 0.1%;
- c) Output impedance less than 400Ω;
- d) Maximum frequency response not less than 50kHz.

5.2.5.2 Voltage output type piezoelectric pressure sensor does not require a charge amplifier and can be directly driven by a data acquisition card with power supply function.

5.2.6 Gas Flow Meter During the gas layer drag reduction test, the gas flow rate is measured. The gas flow meter should have temperature and pressure correction functions, i.e., gas mass... Flow measurement (simulating different draft depths to eliminate the influence of gas compressibility on gas flow measurement). The measurement range is determined based on the hull model or flat plate model. The inner surface area SP of the cavitation cavity on the lower surface of the model is estimated based on the equivalent nominal gas layer thickness $t=0.007\text{m}$. The required gas flow rate Q is calculated as shown in formula (3). $Q = SP \times t \times 3600$ (3) The maximum capacity of a gas flow meter should be 1.5 to 2 times the required gas flow rate, and its accuracy should be no less than 1.5%. A gas flow meter should... A vortex flow meter is used to reduce the impact of humid gas in the pipeline on flow measurement.

5.2.7 Dynamic Signal Acquisition Card The data acquisition A/D card used for dynamic signal acquisition should have no fewer channels than the number of pulsating pressure measurement points, and each channel should be able to acquire data simultaneously. Similarly, the highest sampling frequency per channel is not less than 50kHz, and the A/D conversion resolution is better than 16bit.

5.2.8 Instruments for measuring water velocity and ambient pressure The maximum range of the pressure transmitter used for measuring the test water velocity and negative pressure in the closed-loop circulating water tank should not exceed 150 kPa, and the accuracy should not exceed [missing value]. 0.5%; the maximum range of the pressure transmitter used for positive pressure measurement in the test is not greater than 600 kPa, and the accuracy is not greater than 0.5%. The test is conducted in a towed water tank. The test

speed was determined by the trailer speed, with a measurement accuracy of no more than 0.005 m/s. Ambient pressure was used to measure the subsidence depth using a meter stick, with a measurement accuracy of no more than [missing value]. 1mm.

5.2.9 Barometer The barometer should have a measurement range of 80 kPa to 110 kPa and an accuracy of no more than

0.1 kPa.

5.2.10 Thermometer The thermometer should have a measurement range of -20°C to 50°C and an accuracy of no more than 0.1°C. The water thermometer should have a measurement range of 10°C to 50°C and an accuracy of no more than 0.1°C.

6.1 Ship/Flat Model

6.1.1 Ship Model The ship model (including the hull and appendages) should be geometrically similar to the full-scale design, with a smooth shape, clean surface, and should have a product certificate of conformity. Book. For the design and fabrication of the hull model below the waterline, the total length error of the fully appended ship model should be within $\pm 0.1\%$ Lpp and should not exceed [a certain value]. 10mm, with cross-sectional profile errors within $\pm 0.5\text{mm}$, and the machining precision of each appendage is the same as that of the ship model. If a hull model is used in the experiment... The model is attached to the top of the test section or the model mounting frame by means of a suspension rod. A typical installation example in the water tank is shown in Figure A.1 in Appendix A.

6.1.2 Three-dimensional flat plate model The three-dimensional flat plate model of the local scaled-down test of the typical area where the air cavitation is located on the ship's bottom should be geometrically similar to that of the real-scale local flat plate (air cavitation area). The surface is smooth and has a clean finish. The 3D flat plate model is designed with a certain thickness (e.g., 150mm). If the thickness is too low, its rigidity is low and its deformation is large, which is unfavorable. The box structure (for model installation and experimental measurement) has a semi-elliptical guide section at its head and a triangular wedge-shaped downstream section at its tail. The total length error of the 3D flat plate model is within $\pm 0.1\%L$, and the line shape error of each cross-section is within $\pm 0.5\text{mm}$. The surface of the flat plate is not... The flatness should be within $\pm 1\text{mm}$. For large flat panel models exceeding 5m, a longitudinal and transverse steel frame should be installed internally, and multiple wing-shaped swords should be used. A three-dimensional flat plate model is suspended by a rod to ensure model rigidity. The longitudinal deformation of the model is less than 2mm. A typical installation example in the water tank is shown in Figure A.2.

6.2 Cavitation Model The cavitation model includes a bow gas layer generation device (wedge-shaped block or other shape), a nozzle module, a baffle module, a stern gas