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**Test method for the measurement of pressure fluctuation
induced by the rotor of a ducted propulsor**

带导管推进器转子激励的导管脉动压力测量方法

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Foreword

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

2 Flowchart of measurement uncertainty analysis using the GUM method

11.2 Calculation of measurement uncertainty in catheter pulsating pressure test Based on the influencing factors of catheter pulsation pressure test measurements, the main input quantities affecting the measurement are: test water density, propeller rotation... The calculation process for speed, propeller diameter, accuracy of measuring equipment (including sensors, amplifiers, data acquisition cards, etc.) and repeatability is shown in Table 2.

12 Test Report The test report should include the following.

- a) Test number and name;
- b) Testing instruments and equipment;
- d) Experimental objective;
- e) Testing basis;
- f) Specimen test type;
- g) Test installation and test conditions;
- h) Experimental results and brief analysis;
- i) Test results. Relevant data and charts from the experiment are included in the experiment

report as attachments.

5 Test Instruments and Meters

5.1 Miniature Pulsating Pressure Sensor Miniature pulsating pressure sensors should meet the following requirements.

- a) The outer diameter is no greater than 5mm, or less than 3% of the rotor model diameter;
- b) The height is no more than 12mm, or less than 6% of the rotor model diameter;
- c) The measured frequency response range is greater than 10kHz;
- d) The measuring range is no greater than 200 kPa and the accuracy is no greater than 0.5%.

5.2 DC Amplifier For DC amplifiers used to amplify pulsating pressure signals, the maximum amplification factor should not be less than 1000 times, and the accuracy should not exceed 0.1%. The amplifier should provide an external excitation power supply output.

5.3 Dynamic Signal Acquisition Card The data acquisition A/D card used for dynamic signal acquisition has no fewer channels than the number of pulsating pressure measurement points, and each channel can sample simultaneously. The channel's highest sampling frequency is no less than 10kHz, the A/D conversion resolution is 16 bits or higher, and it has external triggering and internal timing. Clock-triggered sampling function and clock function.

5.4 Speed Encoder An incremental speed encoder should be used to acquire the rotor speed signal. The speed encoder should have both multi-pulse and single-pulse signal output functions, and The number of multi-pulse signals per revolution shall not be less than 128.

5.5 Measurement of water velocity and test pressure

5.5.1 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 its accuracy should not be high. At 0.5%.

5.5.2 The maximum range of the pressure transmitter used for positive pressure measurement shall not exceed 600 kPa, and the accuracy shall not exceed 0.5%.

5.5.3 Conduct the test in a towing tank. The speed is determined by the trailer speed. The measurement accuracy is no greater than

0.005 m/s. The ambient pressure is measured with a meter stick. The depth measurement accuracy is no greater than 1 mm.

5.6 Frequency meter The frequency range for measuring and displaying rotational speed is

not less than 10kHz, and the accuracy is not greater than 0.01Hz.

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

0.1 kPa.

5.8 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 0°C to 50°C and an accuracy of no more than 0.1°C.

6.1 Surface vessel/underwater hull model

6.1.1 The surface vessel model (including the hull and appendages) should be geometrically similar to the full-scale design, with a smooth shape, clean surface, and should possess the characteristics of a product. Certificate of Conformity. The overall length error of the fully attached ship model is within $\pm 0.1\%$ L_{pp} , and the maximum error does not exceed 10 mm. The cross-sectional profile errors are also specified. The difference is within ± 0.5 mm, and the machining accuracy of each appendage is the same as that of the ship model.

6.1.2 The underwater hull model should be geometrically similar to the full-scale design, with a smooth shape and clean surface. It should have a product certificate of conformity, and the hull... The model body and appendages are similar in shape, installation angle, and relative installation position to the real model, and the total length error of the hull model is no greater than $\pm 0.1\%$ L . The maximum error should not exceed 10mm. The profile error of each section of the hull model should not exceed ± 0.5 mm. The machining accuracy of each appendage should match that of the hull model. The original entities are the same.

6.2 Pump-jet propulsion model with duct The pump-jet propulsion model (rotor, stator, and ducts) with ducts is manufactured to the same scale as the ship/hull model and should have... Product qualification certificate is available. The deviations in rotor and stator diameters, chord lengths of each section, and the deviations in the point drilling values of the upper and lower surfaces of each section are not greater than [value missing]. ± 0.1 mm, the diameter and cross-sectional dimensions of the conduit (metal material) are consistent with the rotor's accuracy. This is based on test requirements and the pulsating pressure sensor's dimensions. Several pulsating pressure sensor mounting holes are machined on the surface of the conduit, and corresponding wire grooves are provided around the sensor mounting holes to facilitate sensor mounting. Wiring. A recommended installation arrangement for the pulsating pressure sensor on the conduit surface is given in Appendix A. The gap between the rotor and the conduit in the test model is not... The clearance error is less than 0.75mm, and the deviation from the given value is no greater than ± 0.25 mm. The rotor axial mounting position is consistent with the given position. The maximum error deviation shall not exceed ± 2 mm. For ducted propellers and axial flow pumps, the

machining requirements for pump-jet propulsion models can be referenced.

7 Test Similarity Criteria

7.1 Geometric Similarity The ship and propeller models are all made and manufactured to scale with the actual objects to ensure geometric similarity.

7.2 Similarity of motion The Reynolds number $R_{nm}(0.75R)$ of the blade section chord at $0.75R$ on the rotor of the propeller model exceeds the critical Reynolds number, and is calculated according to formula (1).

7.3 Similar Power In the experiment, the total load factor of the propeller model was equal to that of the actual model, achieving the goal of dynamic similarity between the model and the actual model. That is, the model... The total thrust coefficient is equal to the actual total thrust coefficient. $K_{Tm} = K_{Ts}$, and K_{Tm} and K_{Ts} are calculated according to formulas (2) and (3). (3)

8 Pre-test measurement requirements

8.1 Requirements for Test Equipment and Instruments The equipment and instruments used in the test should meet the following requirements.

- a) The test water should be clean and transparent;
- b) Each ship and propeller model has a unique identifier;
- c) All instruments and meters used in the test are within their metrological validity period;
- d) The instrument should be powered on for at least 15 minutes before measurement.

8.2 Determination of Experimental Parameters The procedure for determining experimental parameters is as follows:

- a) Test pressure. Ensure that the thruster does not generate cavitation, and that the ambient pressure in the circulating water tank/pool during the test is less than the pulsating pressure. Maximum range of the pressure sensor.
- b) Test rotation speed. determined based on the equal load coefficient condition and water velocity.
- c) Test water velocity. Determined to meet the conditions of supercritical Reynolds number and equal load factor, and in conjunction with the rotational speed.
- d) Propeller rotor diameter. The diameter of the propeller model should ideally be between 180mm and 250mm. The specific dimensions should be determined based on the design of the boat model. The design and installation, similarity criteria for testing, and electrical characteristics of the drive motor are comprehensively considered.