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Test methods for submersible motor-pumps

潜水电泵 试验方法

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Test methods for submersible motor-pumps

1 Scope

This standard specifies the performance test and acceptance (or assessment) methods of submersible motor-pumps.

This standard applies to all types of submersible motor-pumps (hereinafter referred to as "motor-pumps"), including the test of all types of submersible motors and submersible pumps.

2 Normative references

The following documents are essential to the application of this document. For the dated documents, only the versions with the dates indicated are applicable to this document; for the undated documents, only the latest version (including all the amendments) is applicable to this standard.

GB 755-2008 Rotating electrical machines - Rating and performance

GB/T 1032 Test procedures for three-phase induction motors

GB 1971 Rotating electrical machines - Terminal markings and direction of rotation

GB/T 3214 Methods for measurement of capacity of pump

GB/T 3216 Rotodynamic pumps - Hydraulic performance acceptance tests - Grades 1, 2 and 3

GB/T 9651 Test procedures for single-phase induction motor

GB/T 10068 Mechanical vibration of certain machines with shaft heights 56 mm and higher - Measurement, evaluation and limits of vibration severity

GB/T 10069.1 Measurement of airborne noise emitted by rotating electrical machines and the noise limits - Part 1: Method for the measurement of airborne noise emitted by rotating electrical machines

GB 10069.3 Measurement of airborne noise emitted by rotating electrical machines and the noise limits - Part 3: Noise limits

GB/T 22714 Test specifications of interturn insulation of form-wound winding for AC low-voltage electrical machines

GB/T 22715 Impulse voltage withstand levels of form-wound stator coils for rotating a. c. machines

GB/T 22719.1 Interturn insulation of random-wound winding for AC low-voltage electrical machines - Part 1: Test methods

GB/T 22719.2 Interturn insulation of random-wound winding for AC low-voltage electrical machines - Part 2: Test limits

3 Test and acceptance criteria

3.1 Guarantee

3.1.1 Guaranteed points

The guaranteed point of the pump shall be determined by the guaranteed flow Q_G and the guaranteed head H_G . The guaranteed point of the motor is determined by the motor's nominal frequency f_N , nominal voltage U_N , nominal power P_N . The guaranteed value is the parameter value, that the motor-pump shall guarantee, at the guaranteed point, which can be the standard specified value, the design value or the agreed value during the acceptance test.

Note: The guaranteed points can be referred to as guaranteed, specified, designed (or nominal), according to different occasions where the provisions are used.

3.1.2 Guaranteed conditions

Unless otherwise specified, the acceptance test shall comply with the following guaranteed conditions:

- a) It shall use the test liquid, which is specified in 3.3.1, on a test bench, which meets the methods, test devices, test conditions, which are specified in this standard.
- b) The performance of the pump, which shall be guaranteed, refers to the performance between the pump inlet and outlet flanges. The pipeline and accessories, on the outlet side of the pump, are not within the scope of the guarantee.
- c) The performance of the motor, which shall be guaranteed, refers to the performance of the motor, which contains lead cable within 5 m. The change in motor performance, which is caused by more than 5 m, is not within the scope of the guarantee.

The test bench shall be provided by the manufacturer, OR it may be provided

The acceptance test is carried out, with the participation of the buyer's representative. The test items shall be negotiated by both parties to the contract. The acceptance result shall be signed by the buyer's witness.

3.2.3 Supervised spot check test

It is the random inspection test of quality, which is conducted by product quality supervision and inspection agencies, as authorized by the competent government departments at all levels of the country. The test content and items shall be in accordance with the relevant product standards AND the relevant documents of the product quality supervision and inspection agency. The test shall comply with the requirements of this standard, be carried out on a certified third-party's test bench OR a test bench of a manufacturer, which is approved by the quality inspection agency.

3.3 Test conditions

3.3.1 Test liquid

The test medium shall be clean cold water OR a liquid, which has the same chemical and physical properties as clean cold water. The characteristics of "clean cold water" shall meet the requirements of GB/T 3216.

3.3.2 Test power supply

The test power supply shall meet the requirements of GB/T 1032.

3.3.3 Length of lead cable of test motor-pump

Unless otherwise specified, the cable length of the test motor-pump shall not exceed 5 m.

3.3.4 Submerged depth of test motor-pump

The test shall be carried out with the motor-pump submerged in water. For submersible motor-pumps, which are used in high-head wells, the pump head can be partially submerged; the submerged depth shall ensure that cavitation does not occur, during the test of the motor-pump.

3.3.5 Stability during the test

3.3.5.1 Operational stability

3.3.5.1.1 Concepts related to operational stability

The following concepts are involved, in determining whether the operation is stable:

- a) Signal average - Usually the measured signal has randomness. The signal average is one of the statistical characteristics of random signals, which is represented by the arithmetic average of n repeated measurements, in an observation period T . The observation period T shall be long enough. When determining T , it shall consider the longest response time of each instrument, in the measurement system AND whether it fully reflects the change characteristics of the measured value.
- b) Fluctuations - The periodic or random changes of the signal, which is output by the measurement system, AND the physical quantities, which are derived from it around the average value over time, are called fluctuations. If the measurement signal fluctuates greatly, due to the structure or operation of the pump, it may use a buffer or damper, that can reduce the fluctuation to the value range, which is given in Table 1, in the measuring instrument or its connecting pipeline. However, it shall be noted that the measures taken cannot affect the "distortion" of the average value of the readings; it shall provide a fluctuation integral, within at least one complete fluctuation cycle. The reduction of the fluctuation range by the buffer shall be bidirectional symmetrical and linear.
- c) Variation - The change in the average value of the output signal of the measurement system and its derived physical quantity.
- d) Reading - The visible observation value, which can be recorded by the output signal of the measuring system.
 - 1) "Quasi-instantaneous" reading: The value, which is read in the shortest possible time (but not shorter than the response time of the measurement system).
 - 2) "Average reading" of the signal: The average value of the signal, which is directly given by a measuring instrument with integral function.
- e) Reading group - The group of n "quasi-instantaneous" readings, which is read during the observation period T . It can be used for statistical analysis and calculation of data (such as the calculation of average, variance, standard deviation).

Compared with the change of the average value, the fluctuation is fast, whilst the change of the average value is slower. According to the change of the average value, it can be judged whether the operation is stable or unstable.

3.3.5.1.2 Allowable reading fluctuation range

Table 1 shows the allowable fluctuation range of each measured value, which is expressed as a percentage of the average value of the observed quantity.

shall not be less than 0.2.

- c) The accuracy level of the power transmitter shall not be lower than 0.5.
- d) The accuracy level of the torque measuring instrument shall not be lower than 0.5; the accuracy level of the dynamometer shall not be lower than 1.
- e) The maximum allowable error of the rotational speed measuring instrument is $\pm 0.1\%$; the accuracy level of the frequency meter shall not be lower than 0.1.
- f) The accuracy level of turbine or electromagnetic flow transmitter shall not be lower than level 1; other flow measuring instruments shall comply with GB/T 3214.
- g) The accuracy level of the spring pressure gauge shall not be lower than 0.4. It may also use the digital measuring instruments (including pressure transmitters), which have equivalent accuracy.
- h) The maximum allowable error of the temperature measuring instrument is $\pm 1\text{ }^{\circ}\text{C}$.
- i) When the automatic test system is used, the measurement uncertainty, which is caused by the measurement instruments of each parameter (including the secondary measurement instrument and the primary sensor or transmitter), shall not exceed the provisions of Table 4.

For all other measuring instruments and measurement methods, which have been calibrated or subject to uncertainty evaluation in accordance with Appendix B, to prove that the uncertainty caused by the parameter measuring instrument (referred to as the system uncertainty), does not exceed the range specified in Table 4, THEN they can be used.

3.4.3.3 Selection and use of measuring instruments

3.4.3.3.1 Pointer instrument

When choosing a pointer type electrical measuring instrument, the measured value shall be within 20% ~ 95% of the instrument range. When using the two-wattmeter method to measure three-phase power, the measured voltage and current values shall be made not less than 20% of the voltage range and current range, respectively, of the wattmeter.

When using a spring pressure gauge, the appropriate measuring range shall be selected, according to the prescribed head of the pump. The indicator value of the pointer shall be more than 1/3 of the pressure measuring range. The

Where:

L - The distance from the pressure measuring hole to the pump outlet flange, in millimeters (mm);

D_j - The diameter of the wellbore, in millimeters (mm);

D_d - The diameter of the submersible motor, in millimeters (mm).

4.4 Electricity measurement

4.4.1 Effective value

Unless otherwise specified, all voltage and current measurements are effective values (rms).

4.4.2 Voltage measurement

The terminal voltage shall be measured from the cable end, which is lead out from the motor. If it is not allowed for measurement on site, it shall calculate the error caused by this AND the reading shall be corrected. When measuring the three-phase voltage, take the arithmetic average of the three-phase voltage, to calculate the motor performance.

For motors of 750 W and below, except for the locked-rotor test, the voltmeter shall be connected to the lead-out cable end of the motor, during measurement; the voltage shall be adjusted to the required value, THEN, read the voltage value at this time. Quickly switch the voltmeter to the power supply terminal AND keep the power supply voltage unchanged; then read the values of other meters. Under the nominal voltage during the no-load test AND under the nominal load during the load test, when the difference, BETWEEN the voltage of the power supply terminal AND the voltage of the motor terminal, is less than 1% of the motor's terminal voltage, the voltmeter can be fixed at the power supply terminal for measurement.

4.4.3 Current measurement

For three-phase motors, it shall measure the line current of each phase of the motor, at the same time. Use the arithmetic mean of the three-phase line currents, to calculate the performance of the motor. For single-phase motors operating with dual windings, it shall measure the main winding current, the secondary winding current, the total current, at the same time.

4.4.4 Power measurement

For three-phase motors, the input power shall be measured by the two-watt meter method or the three-watt meter method. If it needs to obtain more

accurate power measurement values, it may modify it, according to GB/T 1032.

4.5 Measurement of speed or slip

4.5.1 Measuring method of speed or slip

For the measurement of slip or speed, it preferentially adopts the induction coil method. It may also use the other methods; however, the speed sensing element used shall not significantly increase the power consumption OR affect the suction conditions of the pump inlet.

For motor-pumps with special structures, when conventional speed measurement methods cannot be used to measure the speed or slip of the motor-pump, such as a built-in submersible motor-pump, it may use the vibration speed measurement method.

4.5.2 Induction coil method

In the induction coil method, a multi-turn coil, which has an iron core, is sealed and tightly attached to the upper or lower part of the motor case under test (equivalent to the upper and lower extension parts of the motor winding). The coil is connected with a magnetoelectric galvanometer OR a cathode oscilloscope OR a digital slip meter. When using a galvanometer or a cathode oscilloscope, determine the number of galvanometer's light spot swings or the full swing of the oscilloscope waveform, the required time, the power frequency, during the test. The digital slip meter can measure the frequency of the power supply and the slip (Hz) of the motor, at the same time, thereby obtaining the speed of the motor.

4.5.3 Vibration speed measurement method

The vibration speed measurement method is to place the acceleration sensor on the motor-pump or test pipeline; its direction should point to the axis of the motor rotation AND perpendicular to the axis. The speed is measured by spectrum analysis of the vibration signal of the motor-pump, which is output by the acceleration sensor.

4.6 Measurement of DC resistance

The DC resistance between the lead-out cable terminals, from the two phases of the winding cables (hereinafter referred to as the terminal resistance), is measured by a bridge. When the resistance is 1 Ω and below, it shall be measured by a double-arm bridge. When using automatic detection devices or digital micro-ohmmeters and other instruments, to measure the winding resistance, the test current, through the tested winding, shall not exceed 10% of its current in normal operation; the power-on time shall not exceed 1 min. If the resistance is less than 0.01 Ω , the current, through the winding under test,

8 Load test of motor and performance test of pump

8.1 General requirements

8.1.1 For the motor load test, it shall measure the motor input power P_1 , load current I_1 , efficiency η_m , power factor $\cos\phi$, slip rate s (or speed n), output power P_2 , at the nominal voltage, nominal frequency, specified temperature.

8.1.2 For the pump performance test, it shall measure the total pump head H (or full pressure p_i), flow Q , shaft power P_t , pump efficiency η_p , under nominal voltage, nominal speed or nominal frequency.

8.1.3 The method of using the pump as the load shall be preferred. The two tests can be completed at the same time, in one test process, by adjusting the valve opening to change the working condition of the pump AND the output power of the motor, at the same time. The dynamometer can also be used, to do the load test of the motor, but it shall be equipped with a special test device. Submerge the tested motor under water. Make the shaft's extension end be exposed above the surface of the water. Use related measuring equipment and instruments, to connect with the motor's shaft extension end for the test. When limited by the shaft power of the test equipment or pump, under the nominal voltage, it cannot get the satisfactory result of the motor, through the test, at the nominal power, THEN, it is allowed to use the circle diagram calculation method, to find the parameters of the nominal load point.

8.1.4 For the calculation and processing of test results, motor load performance and pump performance shall be carried out separately. The performance of the motor shall be converted to the specified temperature of the motor; the performance of the pump shall be converted to the nominal speed. Unless otherwise specified for vane pumps, the test speed can be within the range of 50% ~ 120% of the nominal speed. When the change of the test speed is within $\pm 20\%$ of the nominal speed, the change in pump efficiency can be ignored.

8.2 Test method

8.2.1 Test method with pump as motor load

Motor load test and pump performance test shall be carried out, at nominal voltage and nominal frequency. Loss analysis and recommended load stray loss methods are used, to determine motor efficiency and pump shaft power. If the maximum current value of the motor, that can be achieved during the test, does not reach the nominal current value, if the motor-pump structure allows, it may increase the motor output power and current, by reversing the motor, to meet the test requirements. In the case that the motor-pump is not allowed to reverse OR reversing cannot reach the nominal current value, it may replace a

8.4.1 State of motor-pump during the test

The motor-pump shall be submerged in the water. Under the nominal frequency, nominal voltage, nominal flow of the pump, pre-operate it for 1 h ~ 1.5 h, according to different structure and power, respectively, until it reaches the stable operation conditions, which is specified in Table 1, Table 2 or Table 3, meanwhile the motor achieves thermal stability. If the load test and pump performance test are carried out, immediately after the thermal test, the pre-operation time can be appropriately shortened. The test shall be carried out, under the condition that the performance of the pump is not affected by cavitation.

8.4.2 Test procedure

The test shall start from the point of minimum power. For centrifugal pumps, it generally starts from zero flow AND gradually increases to more than 140% of the flow guaranteed point OR the valve is fully opened. For mixed flow pumps, axial flow pumps, vortex pumps, it shall start from the full-open state of the valve, gradually reduces to less than 60% of the flow guaranteed point. It shall take 13 ~ 15 different flow points in between them. The flow points taken shall include flow guaranteed points Q_G , 95% Q_G , 105% Q_G , small flow point Q_{min} , large flow point Q_{max} and nominal current point of the pump working range. For centrifugal pumps, it shall also include the zero flow point.

For screw pumps, it generally starts from the zero pressure point (valve fully open), gradually increases to near the pressure guaranteed point. It shall take 10 ~ 13 different flow points in between them. The flow points taken shall include flow guaranteed points p_G , zero pressure point p_{min} , 50% p_G , 75% p_G , 95% p_G , nominal current point. When the flow control valve is fully open AND the pump's outlet pressure does not exceed 0.05 MPa, the outlet pressure is regarded as zero pressure.

When the maximum current value of the motor, that can be measured in the above test process, does not reach the nominal current, if the motor-pump allows, it shall make measurement for another 2 ~ 3 points, when the pump is reversed after the resistance is measured, so that the test current reaches 1.25 times the nominal current. At this time, the flow and pressure do not need to be recorded.

There shall be a certain time interval for each point of measurement, to ensure that the operating point reaches a stable state. At each operating point, the following parameters shall be measured, at the same time, at nominal voltage and nominal frequency:

- a) For three-phase motor-pumps: Read the three-phase current, input power, power frequency, slip (or speed), outlet pressure, flow value;

Appendix B

(Normative)

Evaluation of measurement uncertainty

B.1 General

For the evaluation of measurement uncertainty of the motor-pump test, unless otherwise specified, it only evaluates the uncertainty of the measurement results of the flow, head, speed, pump shaft power, efficiency in the pump performance test. The measurement uncertainty of the pump efficiency is used as the evaluation result of the measurement uncertainty of the test system.

For the evaluation of measurement uncertainty of the motor-pump test, it is formulated, based on the principles, methods and procedures for evaluating and expressing the measurement uncertainty, which is given in JJF 1059.1-2012. It is the specific application of the basic theory of experimental error, in pump testing technology.

B.2 Sources of measurement error and uncertainty in the test

The main sources of measurement error and measurement uncertainty, in the motor-pump test, are:

- a) The maximum allowable error and uncertainty of measuring instruments and sensors;
- b) The fluctuation and change of parameters, which is caused by the unstable liquid flow, due to the non-standardization or imperfection of the design, manufacturing, installation of the test device;
- c) Random changes in the test environment and conditions (such as power supply frequency, voltage fluctuations, room temperature, water temperature, water level changes, etc.);
- d) Instability during test operation;
- e) An artificial deviation in the readings of pointer type instruments (such as spring pressure gauges);
- f) Additional errors, which are caused when the use conditions of the instrument exceed the normal use range;
- g) Approximations and assumptions of measurement methods and measurement procedures;

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