Guideline No. T-06 (202502)

T-06

Low-Temperature Electric-Driven Compressor Expander

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Foreword

The product inspection guideline of China Classification Society (hereinafter referred to as "CCS") specifies the applicable technical requirements and inspection and test requirements for classification products and authorized statutory products of ships to be approved/inspected by CCS.

The Guidelines allow users to adopt alternative test methods and requirements, provided they meet or exceed the standards set by the Guidelines.

The Guidelines are prepared and updated by CCS and published on http://www.ccs.org.cn. In case of any comments and suggestions, please contact CCS via service@ccs.org.cn.

Historical release version and release time: newly edited

Main modifications in this version: None

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Low-Temperature Electric-Driven Compressor Expander

1 Scope of Application

1.1 The Guideline is applicable to electromagnetic bearing low-temperature electric-driven compressor expander which obtains cooling capacity by doing work through expansion in the separation, liquefaction or cryogenic process of air, natural gas and other gases based on the reverse Brayton cycle principle.

1.2 Compressors or expanders with similar structure and principle can also refer to the relevant requirements of the Guidelines.

2 Normative References

2.1 CCS Rules for Classification of Sea-going Steel Ships

2.2 CCS Rules for Materials and Welding

2.3 CCS *Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk*

2.4 International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk and its amendments

2.5 CCS Rules for Natural Gas Fuel Used in Ships

2.6 API617 Axial and Centrifugal Compressors and Expander-Compressors for Petroleum, Chemical and Gas Industry Services

2.7 API618 Reciprocating Compressors for Petroleum and Gas Industry Services

3 Terms and Definitions

The terms and definitions defined in the above survey basis are applicable to the Guidelines. For the convenience of preparation and use, the following definitions are directly quoted or supplemented in the Guidelines.

3.1 Compression-expansion integrated machine: An electric-driven magnetic suspension compression-expansion integrated machine that does work through expansion based on the reverse Brayton cycle principle and is driven by a coaxial motor, so that the compression impeller has sufficient capacity to compress the working medium and make the working medium obtain the required low temperature cooling capacity from the expansion impeller.

3.2 Maximum allowable temperature: During design, the maximum continuous temperature allowed when conveying the specified fluid under the specified maximum operating pressure.

3.3 Maximum allowable working pressure: During design, the maximum continuous gauge pressure allowed when conveying specified fluid at specified maximum operating temperature.

3.4 Maximum continuous speed: It refers to the maximum speed that can be continuously operated with specified fluid under any specified operating conditions.

3.5 Minimum allowable speed: During design,The minimum speed allowed for continuous operation .

3.6 Minimum allowable temperature: During design, the minimum working temperature allowed when conveying the specified fluid under the specified maximum operating pressure.

3.7 Trip speed: The speed at which the variable-speed prime mover stops when an independent emergency overspeed protection device is activated.

3.8 Rated working condition: It refers to the working condition jointly determined by rated speed, rated inlet and outlet pressure, temperature and other parameters.

3.9 Motor power: The maximum continuous power that the motor can output at rated speed.

4 Drawings and Data

The following drawings and data shall be submitted for approval:

4. 1 Drawings/data submitted for product drawing approval:

(1) Table of main performance specifications of the product (including the model, maximum allowable pressure (inlet/outlet), maximum allowable temperature (inlet/outlet), speed, flow rate, motor power and working medium of the product to be accredited);

(2) System schematic diagram (lubrication, sealing, control and safety alarm, balancing (if applicable));

(3) General assembly drawing;

(4) Motor drawing;

(5) Drawings of main parts and components: drawings of main parts and components such as volute, expansion wheel, rotor, impeller, main shaft, stator and magnetic bearing;

(6) List of physical and chemical properties of main parts and materials;

(7) Equipment list;

(8) Process flow chart and main process documents (welding process, heat treatment, etc. (if applicable));

(9) Design calculation sheet (including motor performance calculation sheet (including motor design, rotor dynamics calculation, etc.), strength calculation sheet, etc.);

(10) Product instructions, nameplate and factory certificate sample (if it is used for international voyage ships, Chinese/English version shall be provided);

(11) FMEA analysis report.

4.2 Drawings/data to be submitted for accreditation:

(1) Factory overview: factory name, address, production history, production capacity, technical and inspection personnel, main products, affiliation, product trademarks, etc.;

(2) Details of the product to be approved;

(3) List of main production equipment;

(4) List of main testing equipment;

(5) Brief production process of the product to be approved;

(6) Quality management documents or quality system certificates;

(7) Enterprise registration certificate;

(8) Qualification certificate and/or production license, if applicable;

(9) Product quality certificate or sample of certificate;

(10) Quality control plan, if applicable;

(11) List of qualified suppliers, if applicable;

(12) Type test program.

5 Technical Requirements

5.1 Material requirements

Relevant material requirements shall meet the relevant provisions of CCS *Rules for Materials and Welding*, *Rules for Construction and Equipment of Ships Carrying*

Liquefied Gases in Bulk, applicable guidelines and standards, as well as the requirements applicable to marine environmental conditions.

5.2 Pressure bearing casing

(1) The allowable tensile stress of any material used in the design of pressure bearing casing (excluding bolted connection) shall not exceed 0.25 times the minimum ultimate tensile strength of such material at the maximum specified operating temperature;

(2) For the allowable tensile stress used for connecting bolts on the joint surface of the casing, determine the total bolt connection area according to the hydrostatic test load and gasket preload. The preload stress shall not exceed 0.75 times the minimum yield stress of the bolt material;

(3) The set pressure of the system relief valve shall be specified. The maximum allowable working pressure of the casing shall be at least equal to the relief valve set pressure; if no relief valve set value is specified, the maximum allowable working pressure of the expander casing shall be at least 1.1 times the maximum specified inlet pressure and that of the compressor casing shall be at least 1.25 times the maximum specified outlet pressure.

5.3 Inlet guide vanes, variable nozzles and thermal insulation layer (if applicable)

(1) The compressor expander shall be provided with variable inlet guide vane, variable nozzle and thermal insulation layer;

(2) The inlet guide vane shall be sized to pass at least 110% of the maximum specified mass flow at the minimum specified inlet pressure and the maximum specified inlet temperature;

(3) The actuator shall be able to work under all normal operating conditions, including maximum inlet pressure, maximum flow and minimum outlet pressure;

(4) The inlet guide vane and its actuator shall be able to close with the maximum inlet pressure under all flow conditions.

5.4 Impeller

(1) All accessible weld surfaces on the welded impeller and the precision machined surface of the electro-corrosion impeller shall be inspected by recognized nondestructive testing standards;

(2) The hub and cover plate of the cast impeller shall be subject to radiographic or ultrasonic testing before finish machining;

(3) Each impeller shall be subject to an overspeed test at a speed of 115% of the maximum continuous speed for at least 1 min. The key dimensions of the impeller marked by the manufacturer (such as shaft hole, inlet seal ring and outer diameter of the impeller) shall be measured before and after each overspeed;

(4) After the overspeed test, each impeller shall be fully inspected by magnetic particle or dye penetrant inspection.

5.5 Dynamic balance

The expander impeller, compressor impeller and shaft shall be corrected for dynamic balance, and the dynamic balance accuracy shall meet the requirements of recognized standards accepted by CCS.

5.6 Running clearance

The movement clearance between rotating parts and stationary parts shall meet the requirements of design drawings.

5.7 Shaft

Shafts are to be subjected to non-destructive testing in accordance with a recognised standard, as specified on the drawings and technical documentation approved by the CCS.

5.8 Bearing

The bearing design shall meet the requirements of relevant applicable standards. Compatibility with media and factors such as strength, thermal conductivity and thermal expansion rate shall be considered. Each magnetic bearing shall be equipped with a temperature sensor.

5.9 Assembly requirements

(1) When assembling the nozzle adjusting mechanism (if applicable), it is necessary to carry out low-temperature rotation inspection. When rotating the nozzle ring adjusting mechanism, the load shall be uniform without jamming and uneven weight. After assembly, the clearance between rotating parts and stationary parts shall meet the requirements of drawings;

(2) The parts shall be free of damage, burrs and rust marks in appearance inspection, and the appearance shall be smooth and flat. After assembly, there shall be no defects such as oil stains and bumps;

(3) All non-machined surfaces in contact with lubricating oil, cooling water and processed gas must be cleaned up and treated for rust prevention and corrosion prevention (except stainless steel).

5.10 Critical speed

(1) When the rotor is rigid, it shall be designed to ensure that the actual first critical speed of the rotor is higher than 126% of the maximum allowable continuous speed under operating conditions. The isolation margin can also be determined according to rotor dynamics calculation;

(2) When the rotor is flexible, it shall be designed to ensure that the isolation margin can be determined according to rotor dynamics calculation under operating conditions.

5.11 Noise

Under working conditions, the noise level shall not exceed that specified in the drawings and technical documents approved by the CCS.

6 Raw Materials, Parts and Components

6.1 Main parts and components

Compressor expander motors, frequency converters and electrical control boxes shall be provided with our certificates. Electrical products with explosion-proof requirements shall be provided with product certificates (including explosion-proof requirements) and/or explosion-proof certificates.

7 Type Test

7.1 Selection of typical samples

During accreditation, the selected prototype shall cover the processing capacity and manufacturing level of the factory. The test prototypes shall be selected according to the cooling mode of the series products applied for accreditation and the principle of maximum nominal volume flow under rated exhaust pressure.

7.2 Type test items

7.2.1 Hydrostatic test and tightness test

The pressure-bearing parts shall be subject to hydrostatic test at a pressure of at

least 1.5 times the maximum allowable working pressure but not less than 0.14 MPa, and no leakage is allowed after maintaining the pressure for more than 30 minutes; then air tightness test shall be carried out, with the test pressure being the maximum allowable working pressure, and no leakage is allowed after maintaining the pressure for more than 10 minutes.

After the equipment is assembled, the air tightness test shall be carried out continuously for 30 minutes under the maximum allowable working pressure, which shall meet the requirements of design drawings.

7.2.2 Overspeed test

Each impeller shall be subject to an overspeed test at a speed of 115% of the maximum continuous speed for at least 1 min.

7.2.3 Dynamic balance test

The dynamic balance test requirements for the impeller assembly shall be in accordance with standards accepted by the CCS.

7.2.4 Mechanical running test

(1) The equipment runs from zero to the maximum continuous speed at an increase rate of about 25% without impeller until the bearing temperature, motor temperature and shaft vibration amplitude are stable;

(2) The equipment shall operate continuously for 4 hours at the maximum continuous speed;

(3) Increase the speed to the trip speed and run at this speed for at least 15min (if applicable).

7.2.5 Insulation resistance measurement

The insulation resistance of the compression-expansion integrated machine motor shall be measured, and its minimum test voltage value and corresponding insulation resistance value shall meet the requirements of the corresponding rules and guidelines of the CCS.

7.2.6 Withstand voltage test

The withstand voltage test shall be carried out in accordance with the test voltage conditions required by the corresponding standards recognized by CCS (refer to Article 9.2 of IEC 60034-1:2017 {Ed.13.0} Rotating Electrical Machines - Part 1: Rating and Performance). There shall be no breakdown or flickering during the test. The insulation resistance shall be measured immediately after the test, and the

measurement results shall conform to the above provisions for insulation resistance.

7.2.7 Low-temperature operation test

The actual function verification test shall be carried out for each design condition according to the needs and conditions. The low-temperature operation test can be carried out in the manufacturer, or in the reliquefaction device assembly plant, or on the user's site. The test requirements and process shall meet the drawings and technical documents approved by CCS.

7.2.8 Performance test

According to needs and conditions, the working condition is adjusted by speed adjustment or other measures to change the flow rate and outlet temperature, so that the equipment can meet the design performance requirements. The performance test can be carried out in the manufacturer, or in the reliquefaction device assembly plant, or on the user's site. The test requirements and process shall meet the drawings and technical documents approved by CCS.

7.2.9 Test of safety protection and alarm device

The safety protection utility and alarm device tests shall be carried out according to the safety protection measures approved by CCS, including at least bearing temperature (or integrated monitoring in the system), winding temperature (or integrated monitoring in the system), speed, emergency power failure, suspension state feedback, emergency shutdown ESD (if applicable) and safety valve (if applicable) utility test. Corresponding tests shall be added according to the risk assessment requirements.

7.2.10 Disassembly and inspection

After the compressor expander is tested, it shall be disassembled for inspection as required to check whether there are abnormal quality phenomena in key parts such as main shafts, front and rear bearings, impellers, seal cartridges and seal covers. With the consent of surveyor of CCS, the scope of disassembly and inspection can be determined according to the actual situation or no disassembly and inspection is required.

8 Unit/Batch Inspection

8.1 The inspection for issuing the CERTIFICATE OF MARINE PRODUCT shall be conducted after the manufacturer has completed the required inspections/tests and the product has passed inspections/tests, reaching a deliverable state. The surveyor shall randomly select the products in this batch of low-temperature electric-driven compressor expanders for re-inspection of the following test items according to the principle of sampling at least 1 set per batch/specification, or witness on site when the

manufacturer conducts tests.

8.2 Unit/batch inspection of products from manufacturers that have obtained CCS type approval

8.2.1 Hydrostatic test and tightness test

8.2.2 Insulation resistance measurement

8.2.3 Withstand voltage test

8.2.4 No-load mechanical running test

The equipment runs from zero to the maximum continuous speed at an increase rate of about 25%. During the test, there shall be no abnormality in the equipment.

8.2.5 Test of safety protection and alarm device

8.3 The unit/batch inspection for the products of manufacturers without CCS approval shall include:

(1) The applicant shall submit drawings/technical data to CCS in accordance with the requirements of Article 4 of this Chapter;

(2) Type test shall be carried out for the first product inspection. See Article 7.2 of this Guidelines for type test items;

(3) For products that have undergone type test, the delivery test shall be carried out in accordance with the requirements of Article 8.2 of this Chapter during subsequent product inspection.