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**Fundamental technical requirements for hydraulic
turbines**

水轮机基本技术条件

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Fundamental technical requirements for hydraulic turbines

1 Scope

This standard specifies the performance guarantee, technical requirements, scope of supply, inspection and test items for the design and manufacture of hydraulic turbine products; proposes the requirements to be followed, for its packaging, transportation, storage, installation, operation, maintenance.

This standard applies to hydraulic turbine products, that meet one of the following conditions:

- a) The rated power is 10 MW and above;
- b) For Francis and impulse turbines, the nominal diameter of the runner is 1.0 m and above;
- c) For Kaplan, Deriaz and bulb turbine, the nominal diameter of the runner is 3.0 m and above.

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/T 191 Packaging - Pictorial marking for handling of goods (GB/T 191-2008, ISO 780:1997, MOD)

GB/T 2900.45 Electrotechnical terminology - Hydroelectric powerplant machinery (GB/T 2900.45-2006, IEC/TR 61364:1999, MOD)

GB/T 3323.1 Non-destructive testing of welds - Radiographic testing - Part 1: X-and gamma-ray techniques with film

GB/T 8564 Specification for installation of hydraulic turbine generator Unit

GB/T 9239.1 Mechanical vibration - Balance quality requirements for rotors in a constant (rigid) state - Part 1: Specification and verification of balance

tolerances (GB/T 9239.1-2006, ISO 1940-1: 2003, IDT)

GB/T 9797 Metallic coatings - Electroplated coatings of nickel plus chromium and of copper plus nickel plus chromium (GB/T 9797-2005, ISO 1456:2003, IDT)

GB/T 10969 Specification for water passage components of hydraulic turbines, storage pumps and pump-turbines

GB 11120 Lubricating oils for turbines

GB/T 11345 Non-destructive testing of welds - Ultrasonic testing - Techniques, testing levels, and assessment

GB/T 11805 General specifications of automatic control components (devices) and their related system for hydroturbine-generating sets

GB/T 15469.1 Hydraulic turbines storage pumps and pump-turbines cavitation pitting evaluation - Part 1: cavitation pitting evaluation in reaction turbines (GB/T 15469.1-2008, IEC 60609-1: 2004, MOD)

GB/T 15613 (all parts) Model acceptance tests of hydraulic turbines storage pumps and pump-turbine

GB/T 17189 Code for field measurement of vibrations and pulsation in hydraulic machines (turbines, storage pumps and pump-turbines) (GB/T 17189-2017, IEC 60994:1991, MOD)

GB/T 19184 Cavitation pitting evaluation in Pelton turbines (GB/T 19184-2003, IEC 60609-2:1997, MOD)

GB/T 20043 Field acceptance test to determine the hydraulic performance of hydraulic turbine, storage pumps and pump-turbines (GB/T 20043-2005, IEC 60041:1991, MOD)

GB/T 28546 Specification for package, transportation and storage of large and medium hydraulic units

GB/T 32584 Evaluation of mechanical vibration for machine sets in hydraulic power plants and pump-storage plants

DL/T 443 Guide for factory inspection of hydraulic turbine generator unit and its auxiliary equipment

DL/T 507 Testing regulations for hydroelectric generating set start-up

DL/T 710 Code of operation for hydraulic turbines

allowable runaway time.

4.2.1.8 For the Francis and impulse turbines, the runners should be made of stainless steel. For the Kaplan and bulb turbines, the blades should be made of stainless steel. Other cavitation-prone parts of the turbine should be made of anti-cavitation materials OR take necessary protective measures. If the cavitation-prone parts are surfacing stainless steel, the thickness of the stainless steel layer, after processing, shall not be less than 5 mm.

4.2.1.9 Lifting facilities should be provided on the top of the turbine chamber.

4.2.1.10 When performing shafting calculation, the mass imbalance of the runner is calculated according to the grade G6.3 in GB/T 9239.1.

4.2.1.11 The runner shall be subjected to a static balance test. The mass imbalance of the runner, after static balance, shall meet the requirements of grade G6.3 in GB/T 9239.1.

4.2.1.12 The maximum temperature of the babbitt bearing bush of the thin oil-lubricated guide bearing of the hydraulic turbine, under various operating conditions, shall not exceed 70 °C. The maximum temperature of the radial thrust bearing bush of the horizontal-shaft turbine shall not exceed 70 °C. The maximum temperature of the oil does not exceed 60 °C.

4.2.1.13 The hydraulic moment of the guide vane of the reaction turbine should have a self-closing trend, from near the full opening to near the no-load opening. The water guide mechanism shall be equipped with reliable protection devices (such as shear pins, friction pairs, limit blocks, etc.), to prevent damage to the guide vane and the expansion of the accident. The design of the limit block shall have sufficient rigidity; it should provide a buffer pad. For the protection device combined with the friction device and the shear pin, the breaking force of the shear pin should not be less than 1.5 times the force on the shear pin, which is applied by the servomotor at rated operating force. It should provide hydraulic and manual locking devices, in the fully closed position; it should provide manual locking devices, in the fully open position.

4.2.1.14 There should be a difference in hardness, between the movable wearing ring and the corresponding fixed wearing ring.

4.2.1.15 The arrangement of top cover drainage equipment of the hydraulic turbine should be one in-use and one standby; if necessary, it may be one in-use and two standby. If the top cover of the vertical-shaft turbine has the conditions of gravity drainage, it shall provide a sufficiently large gravity drainage channel.

4.2.1.16 For the reaction turbine, the design of the metal volute and seat ring shall be such, that they can bear the design pressure alone (the maximum

momentary pressure in the volute). In the seat ring design, which adopts the concrete volute, it shall consider the concrete weight and other vertical load, which are supported by the seat ring. For the impulse turbine, the design of water distribution loop shall be such, that it bears the design pressure alone (the maximum momentary pressure in the distribution loop).

4.2.1.17 Exhaust and supplemental air devices shall be provided, on the top of the volute of the horizontal-shaft turbine.

4.2.1.18 The hydraulic turbine shall be provided with a manhole. The manhole, on the volute, should not be less than $\phi 600$ mm. The high head turbine volute should use an inward opening manhole. The size of the manhole, on the tail water tube, should not be less than $\phi 600$ mm or $600\text{ mm} \times 600\text{ mm}$. When a square manhole is used, it shall prevent the four corners from stress concentration and cracking. At the lower side of the manhole, it shall be equipped with a water inspection valve. Reinforcement shall be carried out at the manhole. The location, quantity, size of the manholes shall be as negotiated, between the supplier and the buyer.

4.2.1.19 A light-weight maintenance platform that is easy to disassemble AND has sufficient load-bearing capacity, shall be installed in the tail water tube of the vertical-shaft reaction turbine.

4.2.1.20 When phase-modulated operation is required, it shall provide a phase modulation pressurized water inlet and exhaust device AND a cooling device to reduce the temperature of the small clearance of the runner.

4.2.1.21 For the parts of the hydraulic turbine and its auxiliary equipment, that need to be subjected to pressure test, except for the parts that need to be welded on the site, all need to be pressure tested in the factory, according to the test pressure; the pressure of the pressure test should not be less than 1.3 times the design pressure; the pressure test time shall continue to stabilize for 30 minutes. The pressure-bearing parts shall not produce abnormal phenomena, such as harmful deformation and leakage.

4.2.1.22 The metal volute of the reaction turbine and the water distribution pipe of the impulse turbine, may be subjected to a pressure test, according to the requirements of the contract.

4.2.2 Working stress and safety factor

4.2.2.1 Safety performance analysis shall be carried out in the structural design of hydraulic turbines. In the design of parts subject to alternating stress, vibration or impact, it shall leave sufficient safety margins. Under all expected conditions, it shall have sufficient rigidity and strength.

4.2.2.2 The working stress of the components can be analyzed and calculated

of the runner blade shall not exceed 2/5 of the material's yield strength. For the impulse runner, when it is operating normally, under the expected maximum load conditions, the maximum stress at each part of the runner, which is analyzed and calculated by the classical formula, shall not exceed 1/18 of the material's yield strength. The maximum stress at each part of the runner, which is calculated by the finite element method, shall not exceed 1/9 of the yield strength of the material; meanwhile it shall carry out verification for the fatigue strength.

4.2.2.10 The maximum composite stress $S_{\max}$ of the main shaft is defined as: $S_{\max} = (S^2 + 3T^2)^{1/2}$; its value shall not exceed 1/4 of the yield strength of the material. In the formula, S is the sum of axial stress and bending stress, which are caused by hydraulic load and static load; T is the torsional shear stress, at the maximum power of the hydraulic turbine. It shall calculate AND take into account the maximum composite stress $S_{\max}$, according to the above formula; the maximum stress, after the occurrence of stress concentration, shall not exceed 2/5 of the yield strength of the material. At the same time, the torsional shear stress of the main shaft of the turbine, at maximum power, shall not exceed 1/6 of the yield strength of the material. The main shaft of the horizontal-shaft turbine shall be subjected to verification of fatigue strength.

4.2.3 Material and manufacturing requirements

4.2.3.1 The castings and forgings of the main structural components of the turbine shall comply with CCH-70-4 and JB/T 1270, OR the corresponding standards as stipulated in the contract. For important castings and forgings, the acceptance shall be carried out, under the participation of the representatives of the buyer. The treatment of defects, which are deemed to be major defects, in the above standards, shall be approved by the buyer.

4.2.3.2 Only the welding personnel, who have passed the examination and hold the certificate, can perform the welding work of the main components. The main stressed welds of the main components shall be subjected to 100% non-destructive testing. The weld inspection shall comply with the requirements of GB/T 3323.1, GB/T 11345, NB/T 47013.2, NB/T 47013.3, NB/T 47013.4, NB/T 47013.5, NB/T 47013.10, OR the corresponding standards as stipulated in the contract.

4.2.3.3 The surface of the hydraulic turbine shall have an anti-rust coating. Meanwhile, it shall specify:

- a) Requirements for surface treatment;
- b) Paint and other protection methods, as well as instructions for their use;
- c) Requirements for use before shipment and at the construction site;

- d) Number of coating courses;
- e) The thickness and total thickness of each coating film;
- f) Quality inspection and quality control requirements.

The decorative electroplating layer shall meet the requirements of GB/T 9797.

4.2.3.4 All fasteners, which are in contact with water, shall be made of rust-proof or corrosion-resistant materials, OR it shall take corresponding measures.

4.2.3.5 For bearing bushes, which are made of babbitt alloy, 100% ultrasonic inspection shall be carried out on the combination with the bush base; the contact surface shall not be less than 95%; the single shelling area shall not be more than 1%. The surface shall be free from unaccepted defects, when tested by the penetration method.

4.3 Specific requirements for different types of turbines

4.3.1 Francis turbine

4.3.1.1 In order to ensure the safe, stable, efficient operation of the hydropower station, as well as the life of the flow-through components such as runners, the turbine should not be operated outside the guaranteed scope.

4.3.1.2 When the turbine is operating within the guaranteed range, the hydraulic excitation frequency, as well as the natural frequency of the main flow-through components, such as the runner, movable guide vane, top cover, bottom ring, fixed guide vane, shall be staggered by at least 10%.

4.3.1.3 For the turbines of medium and high head, it may use the leaking water, which is drawn from the upper wearing ring on the top cover, as a backup water source for unit cooling.

4.3.1.4 For the structural design of high-head, high-speed turbines, it shall consider reducing the possibility of lifting the turbine; there shall be measures to prevent the lifting of the turbine.

4.3.1.5 The hydraulic turbine shall be equipped with a natural air supplement device; OR it shall take other measures, to improve the stability of the unit.

4.3.1.6 The runner blades can be cast or molded; the blades should be processed by CNC. The runners of the hydraulic turbine should adopt the group-welding structure.

4.3.1.7 The pre-tightening force of the coupling bolts shall not be less than 3 times the maximum working load, under normal working conditions.

4.3.3.1 When the runner adopts a cantilever structure, it shall consider the influence of the deflection of the main shaft.

4.3.3.2 The single-sided clearance, between the outer edge of the runner blade and the runner chamber, should not be greater than 0.1% D_1 and not less than 0.065% D_1 .

4.3.3.3 The runner chamber shall have sufficient rigidity, to prevent vibration from exceeding the limit. During design, it shall consider the axial displacement of the runner. The parts corresponding to the outer edges of the blades AND other cavitation-prone parts of the runner chamber, should be made of stainless steel or surfacing stainless steel. The natural frequency of the runner chamber shall be at least 10% staggered from the overcurrent frequency of the runner blades.

4.3.3.4 The radial guide bearing should be equipped with a high-pressure oil-lubricated jacking device.

4.3.3.5 The operating mechanism of the runner blades shall be flexible. The association device shall be accurate and reliable. During the seal test of the runner blades, there shall be no oil leakage; no water is allowed to enter the oil supply cavity of the runner body, through the runner seal. If the runner body is filled with oil, the oil pressure shall be higher than the water pressure, which is outside the runner body.

4.3.3.6 An expansion joint shall be provided, between the runner chamber and the lining of the tail water tube.

4.3.3.7 It should not set a manhole on the runner chamber.

4.3.3.8 In order to prevent runaway, it shall provide a hammer to close the guide vanes.

4.3.3.9 The split surface and joint surface of the inner and outer water distribution ring, shall be equipped with sealing strips OR coated with sealant.

4.3.3.10 For the main shaft's coupling bolt, it shall consider working in water AND bearing the influence of alternating stress. The pre-tightening force should not be less than 3 times the maximum working load.

4.3.3.11 The dynamic response analysis shall be carried out for the whole unit, to prevent resonance.

4.3.4 Impulse turbine

4.3.4.1 It shall be possible to assemble, disassemble, replace the runner of the impulse turbine, without disassembling the generator.

4.3.4.2 The runner shall be subjected to dynamic response analysis, to avoid resonance.

4.3.4.3 The runner shall be safe and reliable; it shall be designed according to fatigue strength; it shall be subject to flaw testing, according to CCH-70-4 or the criteria as stipulated in the contract. During operation, it shall also check whether the water bucket has cracks, on a regular basis. After being put into operation, the initial inspection should be carried out within 500 hours of operation.

4.3.4.4 The pre-tightening force of the coupling bolts should not be less than 3 times the maximum working load.

4.3.4.5 The abrasion-prone parts of the nozzle and the needle shall be made of erosion-resistant and abrasion-resistant materials.

4.3.4.6 Each nozzle shall have a separate operating servomotor. Each nozzle shall have a separate stroke indicator; the deflector shall have a position indicator.

4.3.4.7 On the enclosure, it shall take necessary sound insulation or noise reduction measures.

4.3.4.8 The water-stabilizing grid, in the pit of the impulse turbine, shall have sufficient strength and rigidity. Meanwhile, it shall take anti-corrosion measures, to facilitate the disassembly, assembly, maintenance of the turbine runner, nozzles, etc.

4.3.4.9 For the multi-nozzle impulse turbine, the speed control system shall be able to automatically turn on or cut off the number of nozzles running, according to the system load and a predetermined procedure, to ensure stable and efficient operation of the unit; the switching process shall be smooth. During the whole process of nozzle switching and load increase and decrease, the turbine shall be regulated normally; the vibration and swing of the unit shall be within the allowable range. There shall be no interference, between the jets, when all nozzles are working at the same time.

4.3.4.10 The discharge height of the impulse turbine shall meet the requirements, that the safe and stable operation of the turbine and the efficiency are not influenced. At the maximum tail water level, there shall be sufficient ventilation height above the tail water surface. It shall be equipped with necessary air supplement devices on the enclosure.

4.3.4.11 When the tail water level of the power station varies greatly, the installation elevation of the impulse turbine is allowed to be lower than the highest operating tail water level, during the flood season. However, there shall be a compressed air system, to lower the water level in the enclosure.

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