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Specification for design of boiler steel structures

锅炉钢结构设计规范

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Specification for design of boiler steel structures

1 Scope

This document specifies the design principles and methods for steel structures of supported and suspended boilers.

This document applies to the design of steel structures for supported and suspended boilers.

2 Normative references

The contents of the following documents constitute the essential provisions of this document through normative references in the text. Among them, for dated references, only the version corresponding to the date applies to this document; for undated references, the latest version (including all amendments) applies to this document.

GB/T 700 Carbon structural steels

GB/T 1228 High strength bolts with large hexagon head for steel structures

GB/T 1229 High strength large hexagon nuts for steel structures

GB/T 1230 High strength plain washers for steel structures

GB/T 1231 Specifications of high strength bolts with large hexagon head, large hexagon nuts, plain washers for steel structures

GB/T 1591 High strength low alloy structural steels

GB/T 3632 Sets of torshear type high strength bolt hexagon nut and plain washer for steel structures

GB/T 5117 Covered electrodes for manual metal arc welding of non-alloy and fine grain steels

GB/T 5118 Covered electrodes for manual metal arc welding of creep-resisting steels

GB/T 5293 Solid wire electrodes, tubular cored electrodes and electrode/flux combinations for submerged arc welding of non-alloy and fine grain steels

GB/T 5313 Steel plates with through-thickness characteristics

GB/T 12470 Solid wire electrodes, tubular cored electrodes and electrode/flux combinations for submerged arc welding of creep-resisting steels

GB 50009 Load code for the design of building structures

GB 50011 Code for seismic design of buildings

GB 50017-2017 Code for design of steel structures

GB 50019 Code for design of heating ventilation and air conditioning in industrial buildings

GB 50205 Standard for acceptance of construction quality of steel structures

GB 50661 Code for welding of steel structures

JGJ 82 Technical specification for high strength bolt connections of steel structures

JGJ 99-2015 Technical specification for steel structure of tall building

NB/T 47043 Technical specification for manufacture of boiler steel structures

NB/T 47055 Painting and packing specification of boiler

3 Terms and definitions

The following terms and definitions apply to this document.

3.1

Frame structure

A structure, which is capable of resisting shear and bending AND is composed of columns and beams rigidly connected.

3.2

Frame-bracing structure

A structure, that consists of a frame and braces AND together forms a lateral force-resistant system.

3.3

Bracing structure

A structure, in the plane where the beam-column member is located, where bracing members are arranged obliquely, to support the axial stiffness against lateral action.

4 General requirements

4.1 The steel structure of the boiler supports the components of the boiler body; maintains their relative positions; bears wind load, snow load, seismic action; bears the load provided by the design organization of the power station and the load approved to act on the steel structure of the boiler. Except for special requirements, boiler steel structures do not directly bear dynamic loads.

4.2 When designing boiler steel structures, structural schemes, materials, connection methods and structural measures shall be reasonably selected, to meet the strength, stability and rigidity requirements of structural components, during transportation, installation, use.

4.3 The boiler steel structure adopts the limit state design method based on probability theory; calculates with the partial factor design expression; is designed according to the limit state of bearing capacity and the limit state of normal service.

4.4 The limit state of bearing capacity includes: strength failure of components or connections, brittle fracture, unsuitable for continuous load bearing due to excessive deformation, loss of stability of structures or components, structure transformation into a mobile system and structural overturning. The limit state of normal service includes: the deformation affecting the normal use or appearance of structure, components or non-structural components, the vibration that affects normal use, the local damage that affects normal use or durability.

4.5 When designing the boiler steel structure, according to the limit state of bearing capacity, the basic combination and accidental combination of load (action) effects shall be adopted. When designing the boiler steel structure, according to the limit state of normal service, the standard combination of load (action) effects shall be adopted.

4.6 The steel structure of boilers, in areas with seismic fortification intensity of 6 degrees or above, shall be subjected to seismic design. This document is applicable to the design of boiler steel structures, in areas with seismic fortification intensity ranging from 6 to 9 degrees. When the seismic fortification intensity is greater than 9 degrees, it shall follow special provisions.

4.7 The steel structure of boilers, which adopts open-air layout and tight enclosure, shall be checked for wind resistance.

4.8 Components shall avoid the effect of high temperature (above 150 °C). For components subjected to high temperature for a long time, in addition to selecting suitable steel materials, heat insulation or cooling measures shall be taken.

4.9 The temperature segment length (distance of expansion joints) of the steel structure of the boiler shall not exceed 120 m for open-air layout and 150 m for tight enclosure;

the influence of temperature stress and temperature deformation may not be included.

4.10 For boiler steel structures located in cold regions, measures shall be taken during design, to improve the structure's resistance to brittle fracture.

4.11 No matter what connection form is used, for the joints of the boiler steel structure, when the joints are regarded as rigid connections, it shall comply with the assumption that the intersection angle of the members at the joints during the stress process does not change; at the same time, the connection shall have sufficient strength, to withstand all the most unfavorable internal forces, which are transmitted by the joints at the ends of the joint members. When the joint is regarded as a hinge, the connection shall have sufficient rotation capacity, BUT can effectively transmit transverse shear force and axial force.

4.12 The structural safety level of the steel structure of the boiler is Class II; the importance factor (γ_0) is taken as 1.0.

4.13 The natural environmental conditions, which are required for boiler steel structure design, are:

- a) Basic wind pressure value;
- b) Ground roughness category;
- c) Basic snow pressure value;
- d) Seismic fortification intensity (design basic seismic acceleration);
- e) Design earthquake grouping;
- f) Field category;
- g) Operating temperature.

4.14 The boiler steel structure, which is designed according to this document, shall be manufactured and inspected, according to NB/T 47043.

5 Provisions on deformation of materials, design indicators, structural (component)

5.1 The steel structure of the boiler shall be selected, according to the importance of the structure and the working environment and other factors. The main stress structure of the boiler steel structure should adopt Q235 steel, Q355 steel, Q390 steel, Q420 steel; its quality shall meet the requirements of GB/T 700 and GB/T 1591, respectively. When there is a reliable basis, other designations of steel can be used.

- a) The structural self-weight of each part of the boiler body and related equipment, as well as the weight of thermal insulation materials, medium in the pipe, dust accumulation;
- b) The permanent load, which is acted on the steel structure of the boiler by the power station design department and approved.

7.1.2 Variable loads include live loads, wind loads, snow loads acting on the steel structure of the boiler, platforms, operating floors, furnace roofs.

7.1.3 The principle of load value selection of boiler steel structure is as follows.

- a) Self-weight standard value of the boiler steel structure: It shall be determined, according to the design dimensions of the structural parts and the self-weight per unit volume of the material.
- b) The principle of platform load value selection is as follows.
 - 1) The load of the operating floor platform, which acts on the steel structure of the boiler, shall be provided by the design department of the power station. The standard value of self-weight of the concrete platform is 4 kN/m^2 ; the standard value of live load is 8 kN/m^2 . For concrete or steel grating operation floors, the live load of the main girder can be multiplied by 0.7; when the secondary girder is not less than $6 \text{ m} \sim 9 \text{ m}$, the live load can be multiplied by 0.8; when the secondary girder is not less than $9 \text{ m} \sim 12 \text{ m}$, it can be multiplied by 0.7; for column and foundation live loads, it can be multiplied by 0.7.
 - 2) For inspection and access platforms, the live load of the main girder can be multiplied by 0.7. Column and foundation live loads can be multiplied by 0.5.
 - 3) The standard value of the live load of the maintenance platform is 4 kN/m^2 ; the standard value of the live load of the access platform is 2 kN/m^2 ; the standard value of the live load of the ladder platform is 3.5 kN/m^2 .
- c) Roof load: The boiler roof should adopt a light structure; the standard value of self-weight should be calculated according to 0.5 kN/m^2 ; the standard value of live load shall be calculated according to 0.5 kN/m^2 . For components or structures supporting light roofs (purlins, roof trusses, frames, etc.), when there is only one variable load and the horizontal projected area of the load exceeds 60 m^2 , the standard value of the uniform live load on the roof shall be 0.3 kN/m^2 . The snow load is adopted, according to the local meteorological data. Roof live loads are not combined simultaneously with snow loads.
- d) The standard value of the construction or maintenance load of roof panels, purlins, cantilevered awnings shall not be less than 1.0 kN ; it shall be checked at the most unfavorable position.

borne by each node of the boiler steel structure.

- b) Boilers with guiding devices arranged in the open air: According to the standard values of wind load at different heights and the wind-receiving area of the furnace constrained by the guiding devices, calculate the wind loads, which are borne by each guiding device and act on the corresponding positions of the boiler steel structure. In addition to the boiler itself, other equipment (such as various pipes, etc.) acting on the steel structure of the boiler shall be subjected to wind loads to the corresponding positions. At this time, the wind load, which is borne by each node of the boiler steel structure, shall be calculated according to the appropriate wind receiving area.

7.3 Seismic action

7.3.1 For boiler steel structures that have undergone seismic fortification, when they are affected by frequent earthquakes, that are lower than the seismic fortification intensity of the local area, the main structure can continue to be used without damage or repair. When affected by an earthquake, which is equivalent to the seismic fortification intensity of the local area, it may be damaged; however, it can still be used continuously after repair. It will not collapse or cause life-threatening serious damage, when it is affected by a rare earthquake, that is higher than the seismic fortification intensity in this area.

7.3.2 The seismic fortification intensity shall be determined, according to the documents (maps), which are approved and issued by the state. It should use the basic seismic intensity, which is determined by the China Earthquake Motion Parameter Zoning Map.

7.3.3 The boiler steel structure of a power plant, which has a unit capacity of 300 MW and above or a planned capacity of 800 MW and above, belongs to category B buildings; others belong to category C buildings.

7.3.4 When the seismic fortification intensity is 6 degrees, except for the irregular and relatively high boiler steel structures built in category IV fields, the calculation of seismic action and the seismic check of sections may be exempted; however, the requirements for relevant seismic measures shall be met.

For boiler steel structures, which have irregular seismic fortification intensity of 6 degrees and relatively high boiler structures built in category IV fields, as well as the boiler steel structures of 7 degrees and above, they shall be subject to the internal force and deformation analysis under frequent earthquakes.

The elastic-plastic deformation analysis, under rare seismic action, shall comply with the provisions of GB 50011.

7.3.5 When the steel structure of the boiler belongs to category B buildings, meanwhile

shall be considered.

8.6 The load and seismic action shall be handled as follows.

- a) The permanent load and variable load should be input, according to the actual situation.
- b) The wind load shall be dealt with in different ways, depending on whether it is tightly closed or not. Generally, if there is a closed structure, the wind load should be automatically generated by the program; if there is no closed structure, in addition to considering the wind load of the boiler body and related equipment, the wind load of the structure itself shall also be calculated.
- c) The artificially processed seismic action shall be redistributed according to height; the seismic action of the suspended boiler body and drum shall not be redistributed, according to height.

8.7 Check calculation of support force: For the horizontal truss used as the support point of the column, it shall check the support force working condition; the support force shall be determined, according to 10.2.6.

8.8 Overall structural stiffness: Adjust the arrangement of vertical braces and horizontal braces as well as the section of rods, according to the results of space analysis, so that the stiffness of each layer structure changes uniformly, meanwhile avoid torsion and local large deformation of the structure.

8.9 In order to achieve the predetermined goal, the arrangement and section of the rods shall be adjusted, during the calculation process, to achieve the purpose of optimization.

9 Beam design

9.1 Determination of beam section

9.1.1 Select the cross-sectional form of the beam, according to the load conditions, connection methods, transportation, installation requirements.

9.1.2 The cross-section of the beam is generally I-shaped, box-shaped, section steel and their combined cross-sections. The beam with torsion should adopt the box-shaped cross-section.

9.1.3 The beam should be designed as a constant cross-section; variable cross-section girders or horizontal split girders may also be used.

9.1.4 Beams shall meet the requirements for strength, stiffness, stability.

9.2 Calculation of beams

large normal stress, shear stress, local compressive stress at the same time, OR is simultaneously subjected to relatively large normal stress and shear stress, the converted stress shall be calculated, according to the formula (26):

$$\sqrt{\sigma^2 + \sigma_c^2 - \sigma\sigma_c + 3\tau^2} \leq \beta_1 f \quad \dots\dots\dots (26)$$

Where:

σ - The normal stress simultaneously generated at the same point on the edge of the calculated height of the web, in Newtons per square millimeter (N/mm²).

σ_c - The local compressive stress simultaneously generated at the same point on the edge of the calculated height of the web, in Newtons per square millimeter (N/mm²).

τ - The shear stress simultaneously generated at the same point on the edge of the calculated height of the web, in Newtons per square millimeter (N/mm²).

f - The design value of the compressive strength of the steel, in Newtons per square millimeter (N/mm²).

β_1 - Incremental factor of strength design value for calculation of converted stress. When σ and σ_c have different signs, $\beta_1 = 1.2$; when σ and σ_c have the same sign or $\sigma_c = 0$, take $\beta_1 = 1.1$.

f - The design value of the compressive strength of the steel, in Newtons per square millimeter (N/mm²).

σ and σ_c take tensile stress as positive value and compressive stress as negative value. τ and σ_c shall be calculated, according to formula (22) and formula (23). The normal stress (σ) shall be calculated, according to formula (27):

$$\sigma = (M/I_n) y_1 \quad \dots\dots\dots (27)$$

Where:

σ - The normal stress simultaneously generated at the same point on the edge of the calculated height of the web, in Newtons per square millimeter (N/mm²);

M - The section bending moment, in Newton millimeter (N • mm);

I_n - The net section moment of inertia of beam, in quartic millimeter (mm⁴);

y_1 - The distance from the calculated point to the neutral axis of the beam, in millimeters (mm).

9.2.5 When the beam is subjected to bending and the axis is under compression (tension)

$$\frac{M_x}{\varphi_b W_x f} \leq 1 \quad \dots\dots\dots (28)$$

Where:

M_x - The maximum bending moment acting around the strong axis, in Newton millimeters (N • mm);

W_x - The modulus of beam gross section, which is determined by the largest fiber under compression, in cubic millimeter (mm³);

φ_b - The overall stability factor of the beam;

f - The design value of the compressive strength of the steel, in Newtons per square millimeter (N/mm²).

9.2.10 The overall stability factor of the beam shall be calculated, according to the following provisions:

- a) The overall stability factor (φ_b) of the simply supported beam, which has equal cross-section welded I-shape (rolled H-shaped steel) (Figure 5) shall be calculated, according to formula (29):

$$\varphi_b = \beta_b \frac{4.320}{\lambda_y^2} \cdot \frac{Ah}{W_x} \left[\sqrt{1 + \left(\frac{\lambda_y t_1}{4.4h} \right)^2} + \eta_b \right] \sqrt{\frac{235}{f_y}} \quad \dots\dots\dots (29)$$

Where:

φ_b - The overall stability factor of the beam.

β_b - The equivalent bending moment factor for overall stability of the beam, which is adopted according to Table 21.

λ_y - The slenderness ratio -- of the beam between the lateral support points TO the weak axis y-y of the section.

A - The gross cross-sectional area of the beam, in square millimeters (mm²).

h - The overall height of the beam section, in millimeters (mm).

W_x - The beam gross section modulus, which is determined by the largest fiber under compression, in cubic millimeters (mm³).

t_1 - The thickness of the compression flange of the beam section, in millimeters (mm).

f_y - The steel yield strength, in Newtons per square millimeter (N/mm²).

η_b - The asymmetry influence factor of section.

$$\frac{M_x}{\varphi_b W_x f} + \frac{M_y}{\gamma_y W_y f} \leq 1 \quad \dots\dots\dots (31)$$

Where:

M_x - The bending moment around the x-axis at the same section, in Newton millimeters (N • mm).

M_y - The bending moment around the y-axis at the same section, in Newton millimeters (N • mm).

W_x - The modulus of the gross section of the x-axis, as determined by the largest fiber under compression, in cubic millimeters (mm³).

W_y - The modulus of the gross section of the y-axis, as determined by the largest fiber under compression, in cubic millimeters (mm³).

φ_b - The overall stability factor of the beam, as determined by bending around the strong axis, calculated according to the provisions of 9.2.10.

γ_y - The factor of plastic development of the section about the y-axis. $\gamma_y = 1.20$ for I-shaped sections; $\gamma_y = 1.05$ for box-shaped sections; other sections shall be adopted in accordance with Table 8.1.1 of GB 50017-2017. When plastic development is not considered, it shall take $\gamma_y = 1.0$.

f - Design value of flexural strength of steel (N/mm²).

9.2.12 For simply supported box-section beams, that do not comply with 9.2.8, if the cross-sectional dimensions (Figure 6) satisfy $h/b_0 \leq 6$, $l_1/b_0 \leq 95(235/f_y)$, the overall stability may not be calculated. l_1 is the distance between the lateral support points of the compression flange (the support of the beam is regarded as having lateral support).

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