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Hardening and Tempering of Heavy Steel Forgings

大型锻钢件的淬火与回火

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Hardening and Tempering of Heavy Steel Forgings

1 Scope

This Standard specifies the technical requirements and methods (including workpieces to be processed, heat treatment equipment, heat treatment process, heat treatment quality and inspection, shape correction, safety and hygiene requirements, energy consumption requirements and product report) for hardening and tempering of heavy steel forgings.

This Standard is applicable to integral hardening and tempering of heavy steel forgings for heavy equipment in industries like energy, metallurgy and transportation, etc.

This Standard is not applicable to surface hardening.

2 Normative References

The following documents are indispensable to the application of this document. In terms of references with a specified date, only versions with a specified date are applicable to this document. In terms of references without a specified date, the latest version (including all the modifications) is applicable to this document.

GB/T 228.1 *Metallic Materials - Tensile Testing - Part 1: Method of Test at Room Temperature*

GB/T 229 *Metallic Materials - Charpy Pendulum Impact Test Method*

GB/T 230.1 *Metallic Materials - Rockwell Hardness Test - Part 1: Test Method*

GB/T 231.1 *Metallic Materials - Brinell Hardness Test - Part 1: Test Method*

GB/T 4341.1 *Metallic Materials - Shore Hardness Test - Part 1: Test Method*

GB/T 6394 *Metal - Methods for Estimating the Average Grain Size*

GB/T 7232 *Terminology of Metal Heat Treatment*

GB/T 9452 *Testing Method for Working Zone of Heat Treatment Furnace*

GB/T 13298 *Inspection Methods of Microstructure for Metals*

GB/T 13324 *Terminology of Heat Treatment Equipment*

GB 15735 *Requirements for the Safety and Health in Production Process of Metal Heat Treatment*

- a) Smelting furnace No. or batch No. of workpieces;
- b) Quantity and quality of workpieces;
- c) Material nameplate, if necessary, detailed chemical composition of workpieces shall also be provided;
- d) A sketch map of workpieces' appearance and dimensions;
- e) Workpieces' previous process, for example, the mode of molding and processing, and whether heat treatment has been conducted;
- f) If there are workpiece-related inspections, inspection report needs to be provided (including, but not limited to: flaw detection and metallographic report);
- g) Other information.

4.2 Workpiece Appearance

4.2.1 Before hardening and tempering, the surface of workpieces shall manifest no defects like cracks or black scars that might affect the quality of heat treatment.

4.2.2 In terms of workpiece cross-sections that have abrupt changes, smooth transition is requested. There shall be no sharp edges or right angles. Edges and corners shall receive fillet or chamfering processing.

4.2.3 On workpieces, there shall be no blind holes that would affect the quality of heat treatment. If there are blind holes, certain measures shall be adopted towards the parts with the holes.

4.3 Requirements of Acceptance Inspection after Heat Treatment

Before heat treatment, the requirements and methods of acceptance inspection after heat treatment shall be clarified. If there are requirements of sampling and inspection after heat treatment, sampling method, sampling size and testing method shall be determined.

5 Heat Treatment Equipment

5.1 Hardening Heating Equipment

5.1.1 The heating of heavy steel forgings shall select heat treatment furnace that complies with the requirements. Generally speaking, the heating medium shall be air. When workpieces have special requirements, protective atmosphere furnace may be selected.

5.1.2 The testing method of working zone of hardening heating furnace shall comply

5.4 Temperature Measurement and Control Equipment

5.4.1 The type and technical requirements of meter system of heating furnace shall be not lower than Type-D requirements in GB/T 30825.

5.4.2 The accuracy and examination cycle of meter shall comply with the stipulations of Type-III equipment in GB/T 32541.

5.4.3 The selection and application of temperature sensor shall comply with the stipulations in GB/T 30825.

5.4.4 Load thermocouple, which is used to measure workpieces' temperature, shall be able to tightly contact workpieces. Load thermocouple shall be prevented from the influence of radiation and atmosphere in the furnace.

6 Heat Treatment Process

6.1 Hardening

6.1.1 Heating

6.1.1.1 Generally speaking, heavy steel forgings shall adopt the mode of stair-based temperature rise for heating, so that the large thermal stress, which is caused by excessive internal and external temperature difference, may be eliminated. Generally speaking, a suitable furnace charging temperature shall be selected in accordance with the steel grade and dimensions of workpieces. Then, at a relatively slow rate, raise the temperature to elastoplastic transition temperature (generally between 600 °C ~ 700 °C). At this temperature, maintain constant temperature for a while, so that the internal and external temperature of the workpieces are uniform. Then, at a relatively fast rate, raise the temperature to hardening heating temperature.

6.1.1.2 Generally speaking, the hardening temperature of heavy steel forgings shall take the upper limit of hardening temperature of corresponding materials. Please refer to Appendix A for the hardening temperature of commonly used steel grades.

6.1.2 Soaking and holding time

6.1.2.1 Soaking time of heavy steel forgings may be estimated in accordance with experience. Or, load thermocouples may be installed on the surface of workpieces. When the temperature of all the load thermocouples on the surface of workpieces reaches the hardening temperature, start the calculation of holding time.

6.1.2.2 Holding time may be determined through effective thickness of steel grades and workpieces. Please refer to Appendix B for the calculation method of effective thickness of workpieces. Generally speaking, the holding time of carbon steel and low alloy steel shall be calculated in accordance with 0.6 h/100 mm ~ 1.2 h/100 mm. The

Tempering temperature of heavy steel plates may be determined in accordance with technical requirements.

6.2.4 Soaking and holding time

Tempering soaking time of heavy steel forgings may be estimated in accordance with a half of the tempering holding time. If thermocouples are placed on the surface of workpieces, when all the thermocouples on the surface of workpieces reach the holding temperature, start thermal insulation.

Tempering holding time shall be determined in accordance with the effective thickness of workpieces. Under general circumstances, every 100 mm of effective thickness shall at least maintain 2 h of thermal insulation.

6.2.5 Cooling after tempering

The mode of tempering cooling of heavy steel forgings may take Appendix E as a reference.

In terms of workpieces which have requirements towards residual stress, reduce workpieces' cooling rate at above 400 °C to the greatest extent. In terms of steel grades which would easily generate tempering brittleness, corresponding cooling method may be selected in accordance with the specific shapes and dimensions of workpieces.

6.3 Hardening and Tempering Process Curve

Hardening and tempering process curve and parameters of some steel grades may take Appendix E as a reference.

6.4 Process Control

6.4.1 Operators

Heat treatment operators shall receive certain trainings and obtain relevant certificates.

6.4.2 Operating requirements

6.4.2.1 Pre-furnace cleaning and inspection

Before heat treatment, clean and inspect the surface of workpieces, so as to guarantee that there are no surface defects that would affect the quality of heat treatment.

6.4.2.2 Furnace charging

In light of the shape characteristics and performance requirements of heavy steel forgings, reasonable tooling and furnace charging modes shall be designed, so as to control workpieces' distortion after heat treatment. Slender shaft should be vertically placed in heat treatment furnace for heating.

hardness.

The inspection of surface hardness shall comply with the methods stipulated in GB/T 230.1, GB/T 231.1, GB/T 4341.1 or GB/T 17394.1.

7.1.3 Dimension inspection

After heat treatment, corresponding instruments and measuring tools shall be adopted to measure the dimensions of workpieces. The dimensions shall satisfy the final delivery dimensions.

7.1.4 Nondestructive testing

Nondestructive testing of workpieces may be implemented in accordance with the stipulations in JB/T 5000.15. If it is otherwise stipulated in the contract, comply with the contract requirements.

7.1.5 Mechanical property

Workpieces that need mechanical property inspection may comply with the items requested in JB/T 5000.8. In accordance with the requested sampling location and sampling size, take samples of workpieces for inspection. Tensile test shall comply with the requirements in GB/T 228.1; impact test shall comply with the requirements in GB/T 229.

If it is otherwise stipulated in the contract, comply with the contract requirements.

7.1.6 Metallographic inspection

Workpieces that need metallographic inspection may receive microstructure examination and grain size evaluation in accordance with GB/T 13298 and GB/T 6394. If it is otherwise stipulated in the contract, comply with the contract requirements.

7.2 Inspection equipment and personnel

Quality inspection equipment shall comply with relevant stipulations. Measuring instrument shall have a verification certificate issued by metrological service and shall be within the time of validity.

Inspection personnel of all the items shall have a professional qualification certificate.

7.3 Re-inspection and re-heat treatment

7.3.1 Re-inspection

If the preliminary inspection result of mechanical property of workpieces does not comply with the requirements, it is allowed to take a double size of samples from a location that is adjacent to the disqualified samples, then, conduct re-inspection. The

re-inspection result shall completely satisfy the requirements.

If workpieces are disqualified in the mechanical property inspection because of white dots and cracks, then, re-inspection is not allowed. The purchasing party may reject the products.

7.3.2 Re-heat treatment

After the re-inspection, if the mechanical property is still disqualified, re-heat treatment is allowed. After re-heat treatment, re-take samples from the workpieces for the mechanical property inspection. The times of re-hardening shall not exceed two times; the times of tempering shall not be restricted here.

If it is otherwise stipulated in the contract, comply with the contract requirements.

8 Shape Correction

8.1 After hardening, before tempering, shape correction of workpieces is generally needed. The temperature of shape correction shall be lower than the tempering temperature.

8.2 If shape correction is requested after hardening and tempering of workpieces, the temperature of shape correction shall be at least 55 °C lower than the final tempering temperature. After shape correction is completed, conduct destressing treatment at a temperature that is 30 °C ~ 55 °C lower than the final tempering temperature.

8.3 Sampling and performance test shall be conducted after the destressing treatment is completed after shape correction.

9 Safety and Hygiene Requirements

Safety and hygiene requirements of the hardening and tempering process shall comply with relevant stipulations in GB 15735.

10 Energy Consumption Requirements

The energy consumption quota of hardening and tempering process shall comply with relevant stipulations in GB/T 17358 and GB/T 19944.

11 Product Report

In accordance with requirements, product report may be issued. Product report shall include the following content:

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