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Testing method for temperature uniformity of gas heat treatment furnace

燃气热处理炉温度均匀性测试方法

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1 Scope

This Standard specifies the implementation conditions and test cycle, test device, test methods, and evaluation of temperature uniformity of the effective heating zone of gas heat treatment furnaces.

This Standard applies to gas heat treatment furnaces heated by direct combustion gas in the furnace, including cycle (intermittent) and continuous heat treatment furnaces.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

GB/T 1598, Platinum-10%Rhodium/Platinum thermocouple wires - Platinum-13%Rhodium/Platinum thermocouple wires - Platinum-30%Rhodium/Platinem-6%Rhodium thermocouple wires

GB/T 2614, Nickel-Chromium/Nickel-Silicon thermocouple wires

GB/T 4989, Extension and compensating cables for thermocouples

GB/T 4990, Alloy wires of extension and compensating cables for thermocouples

GB/T 7232, Terminology of metal heat treatment

GB/T 9452, Testing method for working zone of heat treatment furnace

GB/T 13324, Terminology of heat treatment equipment

GB/T 17615, Nickel-Chromium-Silicon/Nickel-Silicon-Magnesium thermocouple wires

GB/T 18404, Mineral insulated metal-sheathed thermocouple cables and thermocouples

3 Terms and definitions

Terms and definitions given in GB/T 9452, GB/T 7232 and GB/T13324, as well as the following, are applicable to this document.

3.1

temperature control system error

An offset to the temperature measurement results produced by the temperature control system composed of temperature sensors, extension and compensating cables, display adjustment instruments, etc. Its value is the algebraic sum of the errors of temperature sensors, extension and compensating cables, display adjustment instruments and other components.

3.2

maximum permit error

The allowable error limits of measuring instruments and measuring systems specified in technical specifications and standards.

3.3

correction

The opposite of error. The uncorrected measurement result and the correction are added algebraically to obtain the true measurement result to compensate for the influence of system error.

3.4

initial test

The first test of temperature uniformity of the effective heating zone carried out before the gas heat treatment furnace is put into use.

3.5

cycle test

The test of temperature uniformity of the effective heating zone carried out by the gas heat treatment furnace in use at certain time intervals.

3.6

simulation load test

The size and shape of the bracket or frame used to fix the thermocouple depends on the test method. Such materials shall have sufficient strength and shall have no obvious deformation after testing.

7 Test methods

7.1 Test requirements

7.1.1 The gas heat treatment furnace shall realize automatic temperature control, and the qualified test status shall be able to be reproduced in the production process.

7.1.2 The ambient temperature of the connection parts of the extension and compensating cables, transfer switches, and display instruments shall be controlled, and the temperature change during the test shall not exceed 1 °C.

7.1.3 The initial test shall be carried out with no-load test first, and then the load test after qualification. During the load test, the loading capacity shall be the rated loading capacity of the furnace, or at least not less than 70% of the rated loading capacity.

7.1.4 The cycle test can be carried out in either no-load or load test. When the no-load test fails, the load test can be carried out, and the test result shall be subject to the load test. During the load test, the loading capacity shall be consistent with that of the actual production.

7.1.5 During the no-load test, the measuring ends of the test thermocouples distributed near the burner and flue shall be protected with protective covers. It is also recommended to add protective covers to the measuring ends of test thermocouples distributed in other locations to reduce the impact of temperature fluctuations on the test results. The material of the protective cover shall be compatible with the material of the heat treatment product, the length shall be about 10 times the aperture, and the wall thickness shall be no greater than the thickness of the thinnest workpiece. During the load test, the measuring end of the test thermocouple shall be as close as possible to the workpiece.

7.1.6 The gas heat treatment furnace shall be heated at the heating rate specified by the process. The furnace temperature shall not rise above the test temperature and then drop to the test temperature.

7.1.7 During the test process, all parameters of the furnace shall reflect the normal production operation process of the equipment.

7.1.8 Thermocouples arranged at the corners and end faces of the effective heating area are not allowed to fail. Two adjacent thermocouples are not allowed to fail at the same time. The maximum allowable number of failures for test thermocouples is shown in Table 5.

A unit volume is the volume of pallets, frames, etc. loaded according to the rated loading capacity. The number and location of test points of the unit volume method are determined according to the size of the unit volume, and the distribution of test points shall be able to reflect the temperature distribution within the unit volume. The determination method is as follows:

a) When the width of the pallet or material frame is less than 1.5 m and the length is less than 1.0 m, if the height of the effective heating zone is less than 0.5 m, 3 test thermocouples shall be arranged. 2 thermocouples shall be arranged diagonally at the front and rear end surfaces along the feeding direction, and 1 at the geometric center of the unit volume. If the height of the effective heating zone is not less than 0.5 m and less than 1.0 m, 5 test thermocouples shall be arranged, two of which at each corner of the front and rear ends along the feeding direction, and one at the geometric center of the unit volume. If the height of the effective heating zone is not less than 1.0 m, 9 test thermocouples shall be arranged. One shall be arranged at each of the four corners of the front and rear end surfaces, and one at the geometric center of the unit volume.

b) When the width of the pallet or material frame is not less than 1.5 m and the length is not less than 1.0 m, if the height of the effective heating zone is less than 0.5 m, 5 test thermocouples shall be arranged. 2 thermocouples shall be arranged diagonally at the front and rear end surfaces along the feeding direction respectively, and 1 at the geometric center of the unit volume. If the height of the effective heating zone is not less than 0.5 m and less than 1.0 m, 9 test thermocouples shall be arranged. One shall be arranged at each of the four corners of the front and rear end surfaces, and one at the geometric center of the unit volume. If the height of the effective heating zone is not less than 1.0 m, 11 test thermocouples shall be arranged. One shall be arranged at each of the four corners of the front and rear end faces, one at the center of the front and rear end faces, and one at the geometric center of the unit volume.

c) The schematic diagram of the number and location of thermocouples of the unit volume method is shown in Table 9.

7.4 Test sequence and method

7.4.1 Check the test instruments, test thermocouples, extension and compensating cables, transfer switches, etc. of the test system, which shall be within the validity period of the calibration.

7.4.2 Check the errors of the temperature control system (including thermocouples, extension and compensating cables, and temperature control display parts). The system error calculation is shown in Formula (1). The temperature control system error shall meet the requirements of Table 1. If the temperature control system error does not meet the requirements of Table 1, adjust the temperature control system.

7.4.3 According to the test method, reliably fix or tie the test thermocouple to the selected position such as the temperature measurement frame or workpiece, and add a protective cover if necessary.

7.4.4 Lead the reference end of the thermocouple out of the furnace and connect it to the test instrument as shown in Figure 1. The lead-out position of the reference end of the thermocouple shall not affect the test accuracy. When using an oven temperature tracker, the thermocouple is connected directly to the recorder.

7.4.5 The gas heat treatment furnace heats up at the process specified heating rate. When the temperature of the temperature control system reaches the set temperature, test at no load; when the data changes at each point tend to be stable, start recording the temperature of each test point according to the time intervals and times specified in Table 11; for the load test, when the temperature of the temperature control system reaches the set temperature, record the temperature of each test point according to the requirements of Table 11. The total test time shall not exceed the holding time specified by the process.

7.4.6 Record all test data truthfully in Appendix A.

$$W_j = w_i - w_s \quad \cdots\cdots(3)$$

Where:

W_j – actual value of each test point, in degrees Celsius (°C);

w_i – reading of each test point, in degrees Celsius (°C);

w_s – test system error, which shall be calculated separately at each temperature point and each test point, in degrees Celsius (°C).

7.5.4 Eliminating outliers: If the difference between one of the measured values and the average measured value at that point is greater than 1.8 times the standard deviation, it is considered an outlier and will be eliminated. It shall be noted in the record that this value is not included in the evaluation of temperature uniformity test results.

7.5.5 Testing by the fixed test point method (volume method), the actual temperature value at each test point is the arithmetic mean of each measurement result.

7.5.6 Testing by the moving test point method (section method, unit volume method), the actual temperature value at each test point is the arithmetic mean of each measurement at the same position; if the position of the test thermocouple is continuously changing during the test, the actual temperature of each test point is the instantaneous value of each measurement.

7.5.7 During the no-load test of the pulse burner heat treatment furnace, the minimum or maximum temperature fluctuation at the same test point cannot be greater than 2 times the temperature uniformity; each reading shall be the average temperature of one pulse cycle.

7.5.8 The maximum deviation between the actual temperature at each test point and the set value is the temperature uniformity of the effective heating zone of the heat treatment furnace under test.

8 Evaluation of temperature uniformity of the effective heating zone

8.1 Based on the temperature uniformity of the effective heating zone, compare Table 1 to evaluate the heat treatment furnace category. If the evaluation result is qualified, record it in the effective heating zone temperature uniformity test certificate in Appendix B.

8.2 When the temperature uniformity cannot meet the requirements, the category can be reduced. Under the condition that the temperature uniformity of the new effective heating zone is met, repeated testing is not required.

9 Test records and test reports

Test records and test reports shall include the following content (see Appendix A and Appendix B):

a) Overview of the gas heat treatment furnace under test. Including customer name, gas heat treatment furnace name, serial number, model, category, manufacturing unit, manufacturing date, commonly used temperature, test temperature, temperature control equipment name, heat source name, temperature adjustment method, temperature control sensor insertion depth, effective heating zone size, etc.

b) Temperature measurement system information of the gas heat treatment furnace under test. Including temperature control instruments, recording instruments, temperature control thermocouples, recording thermocouple numbers, models, measurement ranges, accuracy levels, calibration dates, valid dates, etc.

c) Standard information for this test. Including the basis document, the name, model, serial number, measurement range, one of the measurement uncertainty/accuracy level/maximum permit error, effective date of the equipment used (test instruments, thermocouples), and the correction of each test thermocouple at test temperature.

d) Information about this test. Including implementation conditions, loading capacity, furnace atmosphere, effective heating zone location, test point distribution diagram, etc.

e) Test data and results. Including data for verifying or calibrating errors in various parts of the temperature control system; all data for temperature uniformity testing, including set temperature, heating time, air preheating temperature, number of data collections, time of each data collection, temperature controller indication value, tester indication value, temperature uniformity calculation results, temperature distribution line chart of each test point, recommended processing method when the test results cannot meet the requirements, etc.

f) Limitations or restrictions contained in the test.

g) Testing date and validity date.

h) Responsible person (name of tester, reviewer, approver).

10 Management

10.1 All test records of temperature uniformity testing shall be stored in files according to the management system of each unit.

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