How to choose the grade of steel fiber for refractories?

1. Clarify the Main Function of Steel Fibers

The main purpose of adding steel fibers to refractory materials (such as castables, plastics, etc.) is to:

a. Improve toughness: prevent materials from suddenly brittle fracture due to stress concentration at high temperatures or during cooling processes;

b. Enhance resistance to mechanical impact/wear: improve the ability of materials to resist physical impact, scratching, and wear during installation and use;

c. Improve thermal shock resistance: By bridging and suppressing crack propagation, the service life of materials under rapid cooling and heating conditions can be extended;

d. Increase residual strength: Even after cracks appear in the material, it can still maintain a certain level of structural strength.

2. Core Selection Parameters and Level Considerations

The "grade" of steel fibers is usually determined by their material (alloy composition), heat resistance, tensile strength, and geometric shape.

a. Material and heat-resistant temperature (the most critical factor)

This is determined based on the maximum temperature and atmosphere of the usage environment.

a) 430 stainless steel fiber:

Positioning: Medium-temperature economical solution. Suitable for kiln areas with stable operating temperatures below 900°C. For example, certain heat treatment furnaces, boiler linings, and medium-to-low temperature sections of hot air ducts.

Oxidizing atmosphere: Must be used in a clean, dry oxidizing atmosphere. Moisture or reducing gases will accelerate its corrosion.

Cost-sensitive projects: Used when there is strict control over initial investment and the operating conditions are not demanding.

Risks and Limitations: If the actual temperature exceeds its limit, it will rapidly oxidize and fail. The iron oxide scale produced by oxidation not only loses its reinforcing effect but may also expand in volume, potentially cracking the surrounding refractory materials and causing structural damage. Therefore, the use of 430 is strictly prohibited in high-temperature zones, areas with frequent thermal shock, reducing/decarburizing atmospheres (such as cracking furnaces), and environments with acid or alkali corrosion.

b) 304/310 stainless steel fiber:

Type 304: Heat resistance can reach about 900-1,000°C. It performs well in an oxidizing atmosphere and has a high cost-effectiveness, making it one of the most commonly used grades.

Type 310: Contains higher chromium nickel content, with a heat resistance of about 1,050-1,150°C. It has stronger oxidation resistance and is suitable for higher temperature areas.

Usage: Widely used as refractory lining for cement rotary kiln preheaters, decomposition furnaces, and most high-temperature industrial furnaces.

c) 330 stainless steel fiber:

heat resistance range: up to about 1,150°C.
It contains higher nickel and has excellent resistance to carburizing and thermal cycling fatigue.
Purpose: Suitable for high-temperature environments with complex atmospheres (such as carburizing atmospheres) and frequent thermal cycles.

d) Heat resistant alloy fibers (such as 446, 601):

Heat resistance range: up to 1,200-1,300°C or higher.
Features: Contains high chromium, aluminum and other elements, and can maintain excellent oxidation resistance even at extreme high temperatures. Usage: Used for the highest temperature critical parts of kilns, such as around burners, furnace throats, waste incinerators, and other harsh environments.

b. Tensile strength

Fibers with high tensile strength (such as over 1,000MPa) can more effectively transmit stress and suppress cracks. But for refractory materials, the higher the strength, the better. It is also necessary to consider the bonding force with the matrix and the flexibility of the fibers themselves. Generally, medium to high strength (600-1,000MPa) is more commonly used.

c. Fiber shape and size

Shape:
Straight strip: easy to manufacture and low cost;

Wave shaped/hook shaped: It can significantly improve the anchoring force with the refractory matrix, prevent pull-out, and enhance the toughening effect. It is currently the mainstream choice;

Size (aspect ratio L/D):

Length: usually 20-40mm. If it is too long, it is difficult to disperse evenly, and if it is too short, the toughening effect is poor.

Diameter: usually 0.5-0.9mm.

The length to diameter ratio is generally between 40-80. A suitable aspect ratio can achieve a balance between dispersibility, processability, and toughening effect.

d. Addition amount

Usually 0.5%-3.0% of the total weight of refractory materials.

The dosage is too low, and the effect is not significant; Excessive dosage increases costs and may affect the fire resistance and construction performance (such as fluidity) of refractory materials.

The specific dosage needs to be determined through experiments based on the severity of the working conditions and the material formula.

3. Selection Process and Decision-Making Steps

a. Determine operating conditions:

Maximum operating temperature: This is the first criterion for selecting materials.

Atmosphere: oxidizing atmosphere, reducing atmosphere, carburizing atmosphere? Different atmospheres have specific requirements for alloy composition (such as high nickel steel required for carburizing atmosphere).

Thermal shock frequency: Frequent rapid cooling and heating require fibers with better toughness.

Mechanical stress: whether there is material erosion, impact, or structural load.

b. Reference Industry Application Experience:

The cement industry (preheaters, decomposition furnaces) often uses 304 or 310 stainless steel wave fibers.

Steel industry (ladle cover, hot blast stove): Choose 310, 330 or heat-resistant alloy fibers according to the temperature zone.

Petrochemical/chemical (cracking furnace): 310 and 330 alloy fibers are commonly used, considering anti carburizing.

Garbage incinerator: High performance heat-resistant alloy fibers are commonly used in high-temperature corrosion areas.

c. Consider Construction Techniques:

Vibration casting, self leveling casting or spray construction? Different construction methods have different requirements for the dispersion of fibers.

d. Evaluate cost-effectiveness:

On the premise of meeting performance requirements, choose the level with the highest cost-effectiveness. To avoid waste caused by "excessive design" and early damage caused by "insufficient design".

e. Conduct experimental verification (important):

For key projects, it is recommended to conduct comparative tests under simulated working conditions in the laboratory to verify the flexural strength (room temperature/high temperature), thermal shock resistance, and compressive strength of refractory materials after adding selected steel fibers.

4. Practical Suggestions and Precautions

Consulting suppliers: Work closely with technically capable refractory or steel fiber suppliers who can provide professional advice based on a large number of application cases.

View data sheet: Request material report (chemical analysis), melting/softening point range, and tensile strength data for steel fibers.

Mixed use: In some complex working conditions, it is possible to consider using two fibers of different lengths or materials for compounding to achieve better overall performance.

Storage and mixing: Steel fibers need to be stored dry to prevent rusting. During mixing, it should be ensured that the fibers are evenly dispersed in the refractory material to avoid clumping.

5. Summary

The core logic for selecting steel fiber grades for refractory materials is to determine the material grade based on the primary screening condition of temperature, optimize the fiber shape and size according to stress conditions and construction requirements, and finally determine the final model and dosage through experiments and cost analysis.

Simple Decision Reference:

a. <=900°C, in a dry oxidizing atmosphere, grade 430 is cost effective;

b. 900°C-1,000°C, universal oxidation atmosphere: 304 stainless steel fiber is an economical and reliable choice;

c. 1,000°C-1,200°C, strong oxidizing or general carburizing atmosphere: 310 or 330 stainless steel fibers are preferred;

d. >=1,200°C, or extreme corrosive/carburizing atmosphere: Special heat-resistant alloy fibers (such as 601, etc.) must be selected.

Through this systematic analysis, you can select the most suitable steel fiber grade for specific refractory applications, thereby maximizing the service life and reliability of the lining.

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