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**Non-destructive testing - Testing method for
measuring coating bond strength using ultrasonic
wave**

无损检测 涂层结合强度超声检测方法

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Non-destructive testing - Testing method for measuring coating bond strength using ultrasonic wave

1 Scope

This standard specifies the non-destructive testing method of coating bond strength based on the principle of ultrasonic wave, including terms and definitions, personnel qualifications, testing methods, ultrasonic testing equipment, testing conditions, testing requirements, compilation of testing report.

This standard is applicable to coating structures composed of metal and non-metal materials with good sound permeability, including coatings, substrates, bonding layers, including the non-destructive testing of the bond strength of wear-resistant and thermal barrier structures formed by bonding, sintering, chemical and metal bonding.

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) are applicable to this standard.

GB/T 8642 Thermal spraying - Determination of tensile bonding strength

GB/T 9445 Non-destructive testing - Qualification and certification of NDT personnel

GB/T 12604.1 Non-destructive testing - Terminology - Terms used in ultrasonic testing

GB/T 20737 Non-destructive testing - General terms and definitions

GB/T 27664.1 Non-destructive testing - Characterization and verification of ultrasonic test equipment - Part 1: Instruments

GB/T 27664.2 Non-destructive testing - Characterization and verification of ultrasonic test equipment - Part 2: Probes

GB/T 27664.3 Non-destructive testing - Characterization and verification of ultrasonic test equipment - Part 3: Combined equipment

GB/T 34018 Non-destructive testing - Test method for scanning ultrasonic microscopy

3 Terms and definitions

The terms and definitions as defined in GB/T 8642, GB/T 12604.1, GB/T 20737 as well as the following terms and definitions apply to this document.

3.1

Coating bond strength

The average tensile strength or equivalent bond strength per unit area of the interface between the coating and the substrate.

Note: The ratio of the maximum tensile force to the cross-sectional area of the tensile coating when the coating bonding surface is cracked, in Newtons per square meter (N/m²).

3.2

Point bond strength

The bonding strength within the smallest bonding area that can be detected by the ultrasound beam.

Note: The unit is Newtons per square meter (N/m²).

3.3

Equivalent bond strength

The average tensile strength or equivalent bond strength within the equivalent area of the interface between the coating and the substrate.

Note: The ratio of the maximum tensile force corresponding to the cracking of the coating bonding surface to the equivalent cross-sectional area of the tensile coating, in units of Newtons per square meter (N/m²).

4 Personnel qualifications

The personnel who use this standard for testing shall be subject to the ultrasonic testing qualification authentication and certification in accordance

Z_2 - The acoustic impedance of the bonding layer;

Z_3 - The acoustic impedance of the substrate.

The transmission coefficient in formula (3) reflects the bonding state or strength of the interface between the coating and the bonding layer; the transmission coefficient in formula (4) reflects the bonding state or strength of the interface between the bonding layer and the substrate. The transmission coefficient analysis method is suitable for ultrasonic pulse transmission detection method, as shown in Figure 1c).

5.3 Coating bond strength σ

Assuming that the reflection coefficient r_{s1} or r_{s2} during the ultrasound scan is 0 or the minimum value, whilst the transmission coefficient t_{t1} or t_{t2} is 1 or the maximum value, it means that the interface between the coating and the bonding layer at the corresponding point of the ultrasound beam is completely bonded. The ultrasonic signal energy appears full transmission, at this time the corresponding point's bond strength is 1 or the maximum value or equivalent value σ_{th} .

Assuming that the reflection coefficient r_{s1} or r_{s2} during the ultrasound scan is 1 or the maximum value, whilst the transmission coefficient t_{t1} or t_{t2} is 0 or the minimum value, it means that the interface between the coating and the bonding layer at the corresponding point of the ultrasound beam is de-bonded. The ultrasonic signal energy is totally reflected; at this time, the corresponding point's bond strength is zero or minimum.

The expression of coating bond strength σ is equation (5).

$$\sigma = \sigma_{th} \cdot K_r \text{ or } \sigma = \sigma_{th} \cdot K_t \dots\dots\dots(5)$$

Where:

σ - Coating bond strength, in units of Newtons per square meter (N/m²);

σ_{th} - Equivalent bond strength, in units of Newtons per square meter (N/m²);

K_r - Bond strength coefficient of ultrasonic reflection method, which is the ratio of the reflection coefficient of the ultrasound reflection scan to the total reflection coefficient r_{sth} ;

K_t - Bond strength coefficient of ultrasonic transmission method, which is the ratio of the transmission coefficient of the ultrasound transmission scan to the total transmission coefficient t_{rth} .

The bond strength of the coating is the average value of the strength within a

6 Ultrasonic testing equipment

Both ultrasonic reflection and ultrasonic transmission scanning equipment can be used for non-destructive testing of coating bond strength. For coating structures with good sound permeability, it should use the ultrasonic reflection scanning equipment that meets GB/T 27664.3 or GB/T 34018, which have the C-scan function, that is, the thinner the coating, the higher the ultrasonic frequency used for detection and the higher the motion accuracy of the scanning device; for coating structures with poor sound permeability, it should use the ultrasonic transmission scanning equipment that meets GB/T 27664.1 or use the relevant technology to finish the ultrasonic transmission testing; the thicker the coating, the worse the sound permeability; the lower the ultrasonic frequency used for testing, the lower the testing resolution of the bonding state.

The coating bond strength's ultrasonic tester shall have at least the following functions:

- a) The instrument shall meet the frequency requirements of the testing component;
- b) Filter settings;
- c) Ultrasonic excitation voltage control;
- d) Ultrasonic receiving gain control;
- e) The overall stability of the instrument is better than 1%.

The comprehensive performance calibration of the tester shall be carried out regularly; the calibration interval shall not exceed one year.

7 Testing conditions

7.1 The testing process is carried out in a normal temperature environment (10 °C ~ 35 °C); usually deoxygenated water (or distilled water) without gas is used as a coupling agent.

7.2 The surface of the component to be tested shall be smooth and flat; the direction of the detection sound beam shall be kept consistent with the surface normal of the component to be tested.

7.3 The coupling agent is filled between the transducer and the component to be tested; the vertical distance between the two shall be less than the focal length of the transducer.

8.7 Calculation of coating bond strength σ

From the bond strength coefficient K_r of ultrasonic reflection method or bond strength coefficient K_t of ultrasonic transmission method, combined the measured equivalent bonding strength value σ_{th} of the standard specimen, use the formula (5) to calculate the bonding strength σ of the coating.

9 Compilation of test report

9.1 The content of the test report generally includes the following information:

- a) Testing organization, personnel information, testing date, etc.;
- b) The material type, preparation process, size description of the coating structure to be tested;
- c) Ultrasonic transducer model manufacturer and acoustic parameters;
- d) The equivalent bonding strength value σ_{th} of the standard specimen;
- e) Bond strength coefficient K_r of ultrasonic reflection method or bond strength coefficient K_t of ultrasonic transmission method;
- f) Bond strength value σ .

9.2 If the customer requires the original record to be provided, the following information is generally included:

- a) Scan lateral and longitudinal steps;
- b) Resolution and speed;
- c) Scanning area (X-Y size);
- d) Pulse transceiver's energy, gain, bandwidth, repetition frequency, receiving attenuation, damping, sampling rate and filtering and other related parameters.

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