ISO XXXX:XXXX

Non-destructive testing—Test method for measuring residual stress using ultrasonic critical refracted longitudinal wave

Foreword

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ISO XXXX:XXXX was prepared by Technical Committee ISO/TC 135, Ultrasonic testing.

Non-destructive testing—Test method for measuring residual stress using ultrasonic critical refracted longitudinal wave

1 Scope

This standard specifies the test method for measuring residual stresses by using ultrasonic critical refracted longitudinal wave (or called creeping wave).

This standard is applicable to the residual stress or loading stress non-destructive test for metallic and non-metallic solid materials or components which has good acoustic permeability.

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.

ISO 5577:2000, Non-destructive testing - Ultrasonic inspection - Vocabulary

ISO 6892-1:2009: Metallic materials - Tensile testing. Method of test at ambient temperature

ISO 12715:2014: Non-destructive testing - Ultrasonic testing - Reference blocks and test procedures for the characterization of contact probe sound beams

3 Terms and definitions

The terms and definitions given in ISO 5577:2000, DIN EN 10052-1994 are all applicable to this standard.

4 Personnel requirements

The person who will use this standard to test product, have to be trained on this standard and on the technique of measuring residual stress with ultrasonic critical refracted longitudinal wave.

5 Method principle

As shown in figure 1, according to Snell’s law, refraction phenomenon occurs when ultrasonic longitudinal wave oblique incident from a medium with slower wave velocity into another medium with faster wave velocity. If the longitudinal wave refraction angle is 90°, the longitudinal refracted wave will propagate along the surface of the second medium. This longitudinal refracted wave is named Lcr wave, and the corresponding incident angle is called first critical angle. Residual stress (hereinafter abbreviated as stress) in materials affect the propagation velocity of Lcr wave. Generally, when the stress direction is the same as the wave propagating direction, tensile stress reduce the propagation velocity of Lcr wave while compressive stress increase the propagation velocity. If the distance of transmit and receive transducer is fixed and the transit time corresponding zero stress σ_0 and measure stress σ is t_0 and t, the stress σ along the Lcr wave direction in surface layer of the test material can be calculated as

$$\sigma - \sigma_0 = K(t - t_0) \tag{1}$$

or

$$\Delta\sigma = K\Delta t \tag{2}$$

Where， K is defined the stress coefficient, and should be calibrated for every material.

$\Delta\sigma$ and Δt are stress difference and transit time difference respectively.

The measured stress value in accordance with this standard is the surface layer stress average of the sampling region along the Lcr wave propagate direction.

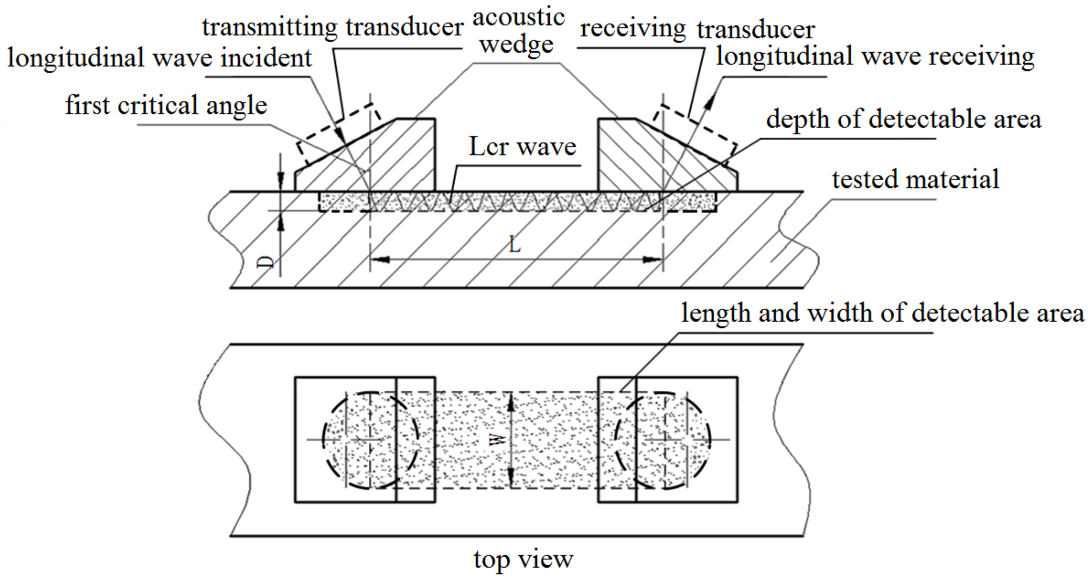

Figure 1 principle and measuring region of Lcr wave stress measurement method

6 Measurement system

6.1 Test instrument

The stress testing instrument should at least have the following functions:

a) Frequency setting

b) Signal filtering

c) Transmitting voltage control

d) Receiving gain control

e) Lcr wave transit time and stress calculation

Performance of the test instrument should be calibrated periodically to ensure the measured value accurate. The calibration interval should be no longer than one year.

6.2 Test probe

6.2.1 The testing probe should be able to transmit and receive Lcr wave.

6.2.2 The ultrasonic transducers (at least 2 transducers) in the probe should be tested according to ISO 12715:2014. Their performance characteristics should be the same.

6.2.3 The probe used for stress test should be the same one when calibrate the stress coefficient and the zero stress transit time.

6.2.4 The contact surface of the probe should engage well with the material surface to be tested. If necessary curved probe contacting surface should be adopted.

6.3 Couplant

Couplant should be used to make the stable and reliable acoustic coupling between the ultrasonic transducer probe and the material surface within the working temperature range. The same couplant should be used in stress testing, zero stress calibration and stress coefficient calibration.

6.4 Zero stress specimen

6.4.1 Material

The metallurgical composition and texture as well as the surface roughness of the specimen material should be the same as those of the material to be tested..

6.4.2 Shape and dimensions

Shape and size of the specimen should be as shown in figure 2. The dimension range are shown in table 1. Dimension tolerance is ±0.1mm. The *Ra* surface roughness of calibration region should less than 10 μm.

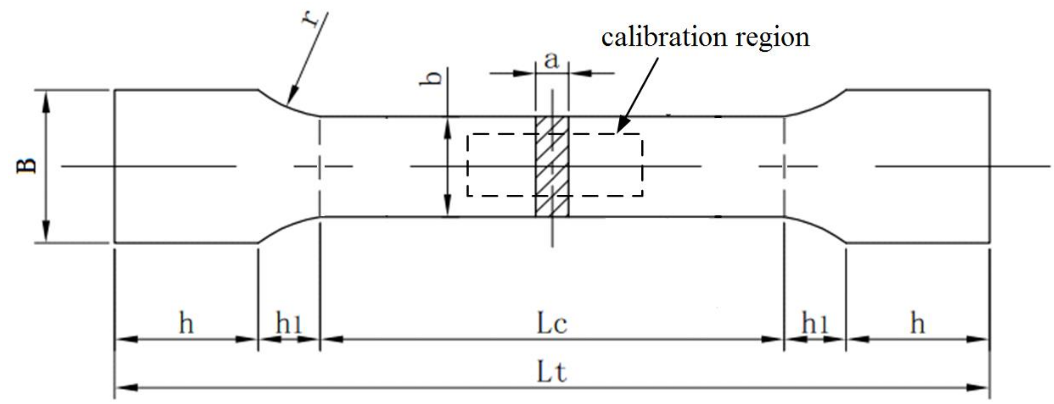

Figure 2 specimen

Table 2 the sizes range of specimen (unit: mm)

thickness (a)	width (b)	Cornering radius (r)	parallel length (Lc)	total length (Lt)	Width (B)	h_1	h
3～10	15～40	≥20	60～240	170～350	30～60	≥15	40～60

6.4.3 Stress relief

In order to relax the residual stress in the specimen, annealing treatment or vibration aging treatment should be done to the specimen.

7 Testing procedure

7.1 Preparereration

7.1.1 Test region

The stress tested with the method specified in this standard is the average of the stress in the surface layer region covered by the probe. The test region dimension is determined by the transducer size, transducer frequency and the distance of the transmit and receive transducer, shown as Fig. 1. The length *L* of the region is equal to the distance of transmit and receive transducer (usually 5mm~100mm), the width *W* of the region is equal to the beam width of the transducer, the depth *D* of the region is determined by transducer frequency and can be calculated with the experimental equation

$$D = \alpha \times f^{-0.96} \qquad (2)$$

Where ： D — penetration depth of the Lcr wave （mm）;

f — center frequency of the transducer （MHz）;

α —penetrating coefficient （mm/ns）， for common metal, $\alpha_{steel} = 5.98$ ，

$\alpha_{aluminum} = 6.40$ ， $\alpha_{copper} = 4.81$

7.1.2 Test Probe Prepare

Design the ultrasonic transducer layout according to the test region description in 7.1.1.

7.1.3 Test Surface Prepare

The *Ra* surface roughness of the test spot should be less than 10 μm.

7.2 Test Instrument adjustment and setting

Operate the test instrument according to its operating manual, make it working normally.

Set test frequency, filtering bandwidth, transmitting voltage, receiving gain, transducer distance and probe position according to the test region (7.1.1) requirement.

7.3 Calibration of the stress coefficient

Adjust and set the instrument according to the description of 7.2, steadily couple the probe to the calibration region of the zero stress specimen (6.4), Carry out the tensile test according to the method defined in ISO 6892-1:2009 with ambient temperature at 22±2℃.

Carry out the tensile test with ambient temperature at 22±2℃. Measure stress and transit time increment $\Delta\sigma$ and Δt at least 10 point in the elastic stress range of the material , repeat tensile test at least 5 times and take the average of measured stress and transit time increment as calibration data. Figure 3 shows a example calibration data, the relationship between transit time increment Δt and stress increment $\Delta\sigma$. linear fitting method should be used to process the stress and transit time data to obtain the fitting line. The reciprocal of the fitting line slope is the calibrated stress coefficient K.

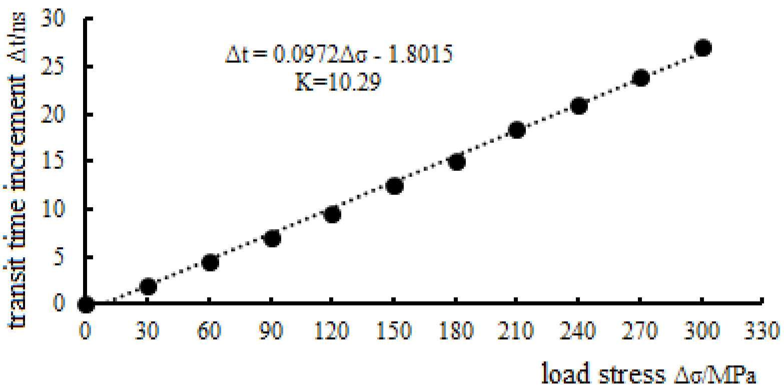

Figure 3 relationships between tensile stress and transit time

(Test conditions are as follows: the frequency of transducers are 5MHz, the transit distance between transducers is 30mm, the material of the specimen is 45# cold rolled steel and environment temperature is 23℃)

7.4 Zero Stress transit time calibration

Adjust and set the instrument according to the description of 7.2, steadily couple the probe to the calibration region of the zero stress specimen (6.4). Record the Lcr wave transit time t_0 corresponding to zero stress.

7.5 Stress Measurement

7.5.1 Adjust and set the instrument according to the description of 7.2, Couple the probe prepared according to 7.1.2 to the measurement position.

7.5.2 Record the Lcr wave transit time t in test material.

7.5.3 Calculate the stress $\Delta\sigma$ or σ（if σ_0＝0）in the tested material using equation (1) or (2). Positive value indicate tensile stress and negative value indicate compressive stress.

8 Temperature compensation and correction

The temperature difference when conducting stress measuring and when conducting calibration should be no more than ±15℃ and the measurement error deduced by temperature variation should be corrected. If the test temperature is out of this range, special probe and couplant should be used and the stress coefficient and zero stress transit time should be calibrated accordingly.

Temperature variation will cause Lcr wave speed change and then cause stress measurement error. To assure the measurement accuracy, the measurement error deduced by temperature variation should be corrected. To implement the compensation the relationship between temperature and Lcr wave speed(or the transit time for specific probe) should be found from experiment or material data manual.

9 Test report

The items in the test report should at least include：

a) Test agency, Test personnel, Testing date,

b) Tested material, thickness, surface roughness and curvature description,

c) Probe center frequency, transducer distance, Instrument filtering bandwidth and gain,

d) Test temprature

e) Ttest spot location, and orientation, test region size,

f) The measured stress value.