MEASURMENT OF THE VELOCITY PROPAGATION OF ULTRASONIC WAVES IN CASTINGS

ИЗМЕРЕНИЕ РАСПРОСТРАНЕНИЯ СКОРОСТИ УЛЬТРАЗВУКОВЫХ ВОЛН В ОТЛИВКАХ

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Abstract: *Ultrasonic testing (UT) of castings is common foundary practice. For the correct calibration of UT, it is necessary to measure the velocity propagation of the ultrasound waves in the castings. It is inverse ultrasonic problem. A method for velocity measurement, according to ASTM E 494: 2015, with one-sided access to the casting, is being considered.*

In this article the equations for determined of transversal and longitudinal velocities propagation - $(V_T;V_L)$*, through measurement: distance between transducers (source-reflector) -* $2.W^X$ *and the time of propagation -* (t_T^X) *are obtained.*

KEY WORDS: ULTRASONIC WAVES, CASTING

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1. Introduction

Ultrasonic testing (UT) of castings is common foundary practice [1,2,5]. For the correct calibration of UT, it is necessary to measure the velocity propagation $(V_T;V_L)$ of the longitudinal and transversal ultrasound waves in the castings. It is inverse ultrasonic problem. A method for velocity measurement, according to ASTM E 494:2015, with one-sided access to the casting, is being considered.

2. Evaluation of the velocity V_T

The measurement of the velocity of transverse ultrasound wave propagation - $V_T \equiv V_T^X$ in castings at one-sided access to the casting is been considered, The velocity V_T^X by Snellius's law,[3], fig.1. is calculated i.e.

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$$(1)\qquad \frac{\left(V_T^X\right)^2}{\sqrt{\left(V^{(1)}\right)^2-\left(V_T^X\right)^2\sin^2\vartheta_{1b}}}=\frac{W^X}{t_T^X\sin\vartheta_{1b}},$$

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where $V^{(1)}$ - ultrasonic velocity of the protector in the transducer, ϑ_{1b} - incidence angle, W^X - distance between transducers (source-reflector), t_T^X is time of propagation of transversal ultrasonic wave . The value $2.W^X$ is calculated through expression $2.W^X=W_F+W_L+W_R$, where W_F is distance between foreheads of transducers, W_L and W_R are distances between foreheads and centers of left and right transducers respectively.

The Snellius's law, (1), in pitch and catch ultrasonic technique, fig.1., is transformed to

$$(2)\qquad \varphi\left(p.V_T^X\right)-W^X/.\left(p.t_T^X\right)=0$$

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where $\varphi\left(p;V_T^X\right)=\frac{(pV_T^X)^2}{\sqrt{1-(pV_T^X)^2}}$, $p=\frac{\sin\vartheta_{1b}}{V^{(1)}}$ - beam parameter.

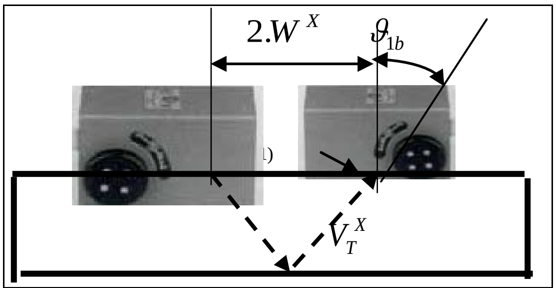

Fig 1. *Pitch and Catch ultrasonic technique*

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The value of V_T^X in (2) by means the Newton's method [4] in $(2000\div5000).m/s$ is looking for.

The algorithm ZEROIN [4]. is used .This algorithm is fast approaching and robust .

The velocity V_L^X of propagation of longitudinal ultrasonic wave is calculated by equation [3].

$$(3)\qquad \frac{V_T^X}{V_L^X}=\sqrt{\frac{1-2.\nu}{2-2.\nu}},$$

where ν - Poison's ratio. For most castings, the reference values for ν may be adopted $\nu\in(0.23\div0.28)$ [1]. In this case the equation (3) is reduced to

$$(4)\qquad V_T^X/V_L^X\approx(0.592\div0.553).$$

Therefore

$$(5)\qquad V_L^X\approx(1.689\div1.808)..V_T^X.$$

3. Calibration at UT of castings

The basic parameter of the UT calibration, for ultrasonic flaw detector, is the velocity of ultrasonic propagation $V_T^X\equiv$ (MTL VEL), fig.2. The values of W^X and t_T^X in (2) are measured [3] .

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Fig.2. *Display of calibration parameters for UT of castings*

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The other calibration parameters at UT: (dB, RANGE, D-DELAY, P-DELAY), fig.2. are clear.

4. UT of castings

The main task at UT of casting, the reflected area of unknown discontinuity - S_X is evaluated. The result from the analysis of acoustical tract [2] is the equation (6) for S_X.

(6) $q(x).S_X - \tilde{p}_S(x) = 0,$

where $q(x) = \dfrac{D_J.S_{PP}.\cos\beta}{(V_T^X / f)^2.(R(x)+r_{PP})^2}$.

In (6) the parameters are two groups:

A/ Assignment parameters: D_J - energy transmission factor, S_{PP} - area of piezo ceramic plate, β - angle of refraction, f – frequency.

B / Evaluated parameters: V_T^X - the evaluated value for velocity of transversal ultrasonic wave in the casting for calibration, $(R(x)+r_{PP})$ - distance "source – reflector".

The ratio of acoustical pressure - $(\tilde{p}_s(x))$ by the amplification $N, dB = -20\lg(\tilde{p}_S(x))$ is evaluated.

The solution of (6) is S_X, where $q(x)$ and $\tilde{p}_S(x)$ are known.

The equation (6) is inverse problem at UT for sensitivity [2,5].

5. Sizing error at UT of castings

If done incorrect calibration, there is error of sizing. The relationship between error of refracted area - $\Delta S_X,\%$ and error of ultrasonic velocity - $\Delta V,\%$ is

(7) $\Delta S_X,\% = (\Delta V,\%)^2 + 2.(\Delta V,\%),$

where

$$\Delta S_X,\% = \frac{S_X - S_X^{(m)}}{S_X^{(m)}}100\%,$$

$$\Delta V,\% = \frac{V_T - V_T^m}{V_T^m}100\%.$$

$(S_X^{(m)}; S_X)$ are respectively measurement and used area of reflectors,

$(V_T^m; V_T)$ are respectively measurement and used velocity of transversal ultrasonic waves.

For example:

A/ If take it $\Delta V,\%$ = (1-2) % (which is acceptable accuracy for velocity V_T^m measurement), then, according (7), $\Delta S_X,\% \approx$ (3-8) % , which is a good result.

B/ If take it $\Delta V,\% >$ (3-5) % (which is not acceptable accuracy for velocity V_T^m measurement), then , according (7), $\Delta S_X,\% >$ (15-35) %., which is a bad result.

6. Conclusion

The calibration condition at UT of castings was obtained. The main parameter of calibration is velocity of ultrasonic propagation V_T^X. An equation (6) for determining of V_T^X is obtain. The velocity of propagation V_T^X is measured through the time of propagation - t_T^X of transversal ultrasonic wave and distance between transducers (source – reflector) - W^X The sizing of unknown discontinuity - S_X is evaluated by (6) after correct calibration at known velocity V_T^X.

By its very nature, the calibration process at UT of castings is essentially the inverse ultrasonic problem [5].

7. Literature

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