Flaw size evaluation according to FD indications

Users manual

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Wroclaw 05.2004
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Flaw size evaluation upon the FD indications is a one of the basic task in ultrasonic examinations. There are some method how to do that and their descriptions can be found in many books and standards. Selected method of flaw size estimation are described here (especially these implemented in CUD programs).

The flaw is characterized by visible indications on FD screens (echo amplitude $A$ and distance of ultrasonic beam $L$). Additionally the data characterizing the position of probe on the examined element can be attached. Knowing probe angle, the distance $L$ and probe position we can easily calculate the position of the flaw in XYZ coordination. So the flaw can be characterized by its location ($X_i$, $Y_i$, $Z_i$) and its amplitude $A$.

In ultrasonic examinations the flaws are divided into:
- small flaws (discrete ones), which size is less than the transducer size,
- large flaws - linearly aligned and wide ones.

In the methods of estimation of large flaws the flaw size (its length) is determined upon the observation of echo amplitude and probe movements (according to X or Z axle). The 6dB fall of amplitude (in respect to maximum echo amplitude) determines the end of the flaw.

Estimation of small flaws

Two methods are mostly used : DGS and DAC

1. DAC method
The DAC method is designed for flaw evaluation through the comparison the echo (amplitude) of real flaw to the echo of model one. This method is very popular in American standards. The model flaws create a DAC curve which connect on the screen peaks of echoes coming from the artificial (model) flaws with the same diameter, but differ distances from the probe. The model flaws can be made in calibration block (e.g. showed in fig. 1), which is usually made from the same material as tested element. In DAC method the model flaws are the side-drilled holes. Some of FDs (e.g. CUD) can save the curve and invoke it on request.

Fig. 1 Calibration block for DAC creation (for skew and normal probe)
In fig.6 a DAC curve \textit{abb} made with calibration block (fig.1) is shown. In curve description (not displayed here) the next data are stored: the diameter of artificial flaw (3mm in this case), the probe name and material name. According to fig.2, the detected flaw is located 22.8mm from probe and its echo (amplitude) is 1dB less than echo of 3mm artificial flaw.

\textbf{Fig.2. Flaw evaluation with DAC curve}

\textbf{2.DGS (AVG-OWR) method (flat bottomed holes)}

The DGS method was worked out in the 1960’s at Krautkrammer Company and is present in many standards (especially in Europe). This method has many advantages and is easy to apply in digital FD that enables it to display directly the size of tested flaws (as equivalent one). With the universal DGS chart this method is universal because it can be applied to any probes, any materials and no special calibration block is required.

\textbf{2.1. The real flaw and the equivalent one}

In fig.3 and 4 the calibration blocks with flat-bottomed holes are shown. Their bottoms represent the model flaws called the equivalent ones.

It is difficult to estimate the relationship between the real flaw and equivalent one. Many authors give the divergent studies. So some of the examination standards give the extra condition for applied DGS method (e.g. measurement of probe movement, observation of echo, etc.) The DGS method is commonly used because of its advantages such as recurrent indications, digital processing possibility, universality. These advantages make this method better than other ones.

\begin{figure}
\centering
\includegraphics[width=0.5\textwidth]{fig3.png}
\caption{Calibration block for skew probes (DGS method)}
\end{figure}

In fig.1 the position of probe in calibration block is shown to achieve the echo of equivalent flaw with d diameter and infinity diameter.
Remark
The calibration block must ensure the perpendicularity of ultrasonic beam to reflector, which is the bottom of the hole with d or infinity diameter. The bottom of holes must be made precisely (it is enough to deepen the drilled hole with the mill).

2.2. Universal DGS chart
The DGS method is very similar to the DAC one. But its advantage is that single DGS curve can be recalculated making curve independent from concrete probe and material. The set of such curves makes universal (normalized) DGS chart. This chart is available in many books. In this chart the distance term is replaced with normalized one (A), the diameter of the equivalent flaw size with normalized diameter R. Basing on this chart and stored probe data the size of equivalent flaw (d) can be easy calculated.

The 20dB value represents the hypothetical difference of echo amplitude between infinity diameter of flaw and current one.

The relationship between data are described in the next formulas:
\[ R = \frac{d}{D_{ef}} \Rightarrow d = R \times D_{ef} \]  
\[ A = \frac{Z}{N} \]  
\[ N = \frac{(D_{ef})^2 f}{4C} \]

Where:
- \( d \) – diameter of reflector, \( D_{ef} \) – effective diameter of transducer (\( D_{ef} = 0.96D \) for round transducer, \( D_{ef} = 1.15D \) for square transducer, \( D \) – diameter or size of transducer),
- \( C \) – velocity of ultrasonic wave (km/s), \( A \) – normalized distance from transducer to reflector, \( Z \) – the real distance from transducer to reflector (displayed L distance plus offset in probe), \( N \) – near field length

Fig.4 Calibration block for normal probes (DGS method) with flat bottomed holes.
2.3. Automated flaw evaluation

The DGS method implemented in CUD enables to read the equivalent flaw size directly from the screen. In fig. 6 such situation is presented. The echo of flaws crossing the MFix marker automatically invokes its evaluation (D=3.1mm with distance L=38.9mm).

2.4. Limitation of DGS method

The authors of this method do not give the limitation to this method, but upon examination with calibration block we suggest some limits:

- do not apply this for evaluation for flaw greater than 0.6 Defl
- do not apply for distances greater than 5N

These limitations can be easy omitted through the probe with larger transducer or through the control measurements with special calibration block (fig. 3 and 4)

Fig. 5. AVG-Diagram (OWR-DGS) according to [www.ndt.net/article/az/ut_idx.htm](http://www.ndt.net/article/az/ut_idx.htm)

**Fig. 6 Equivalent flaw size**