1.12.29. ULTRASONIC INTROSCOPY OF WELDED JOINTS FOR NUCLEAR ENGINEERING

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The improvement of product quality information can be obtained employing introscope ultrasonic images. Multipurpose single- and double-channel ultrasonic introscopes: "IMIN-96", "IMIN-1C" and "IMIN-2C" are used for automatic testing of various types welded joints with wall thickness in the range 0.5 – 10 mm. These introscopes have been designed and manufactured in the Bochvar Institute of Inorganic Materials. The introscopes are PC-based hardware-software complexes. Introscopes work in the frequency range 10 – 50 MHz using pulsewidths 20 – 50 ns. A resolution for magnitude of cold weld openings and cracks is about 0.5 μm. The introscopes control scanners on which test specimens or parts and ultrasonic transducers are fixed. The scanners have steppers providing a reciprocating motion of ultrasonic transducers and rotation or movement of test parts. As a result, using known coordinates of the transducer and parameters of a measured signal, the computer creates the 2D color images of welded joints.

Besides the conventional ultrasonic images (A-scan, B-scan, C-scan) the algorithms of new types ultrasonic images – a layer-by-layer image and "sum" image of sections have been implemented in these introscopes. To obtain a layer-by-layer ultrasonic image, a selected zone is split into layers and the presence of signals at each layer is analyzed. After that the quality assessment is carried out according to a pre-set algorithm and each layer is assigned with a definite color code. To obtain ultrasonic image of "sum" section of the whole region test zone, the new type scanning process called LB-scan has been developed in Bochvar Institute. The LB-scanning creates images of sections of a test zone, like B-scan, and connects the end of an image with the beginning of the next one during scanning. Thus, an image of the all inspected volume is gained. The method of LB-scanning combines simplicity of an ultrasonic path set-up and an improvement of testing accuracy and sensitivity. For thin-wall constructions (0.1 to 0.5 mm) with two or more acoustic interfaces, like a weld joint with backing strap, a C-scanning time division of pulses reflected from all surfaces and internal slacknesses of cast metal is carried out with accuracy up to $(4 – 6) \cdot 10^{-7}$ seconds. A LB-scanning time division is carried out to with accuracy up to $(4 – 6) \cdot 10^{-9}$ seconds. Thus, the LB-scanning considerably simplifies instrumentation adjustments and the scanner's construction.

The application of only one ultrasonic transducer is often not enough to detect and to size imperfections. Therefore, there are two channels with a direct and angle transducers automatic switching in "IMIN-2C". A real time record is carried out simultaneously for the both channels. When using a direct transducer to define the depth of cold weld, there is a reflection of longitudinal waves ultrasonic pulses from the top of the cold weld in the case its size r is more than $\lambda/2$ (where λ is a wavelength). $\lambda/2 \approx 60$ μm in steel parts at the frequency of 50 MHz. Using focalizing transducers with $r > 60$ μm a reflection of pulses from the top of the cold welds registered. The weld depth (h) is determined as $h = tc / 2$, where t is a travel time of an ultrasonic pulse and c is a sound velocity. When a value of c is known h can be defined enough precisely (5 – 10%) by measuring t.

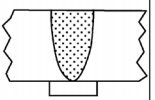
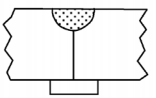
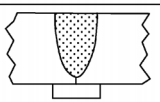
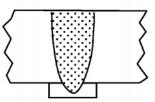
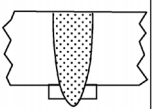
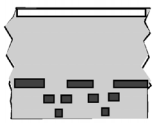
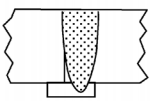
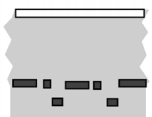
№	Section of of a weld joint	Ultrasonic Images		Weld quality evaluation
		Layer-by-layer	LB – scan	
1				The depth of the weld foundering is equal to the width of the part. A weld is normal
2				The depth of the foundering is much less than the width of the part
3				The depth of the foundering is slightly less than the width of the part
4				The depth of foundering is more than the width of the part, but it does not go below the backing strap. A weld is normal
5				The foundering is deeper than for normal case
6				The depth of the weld is normal, but the cast zone of the weld is shifted relatively of butt joint

Fig. 1. The Catalogue of Ultrasonic Images of Weld Joints with Backing Strap

If a size of the top of the cold weld is $r < \lambda / 2$, h is evaluated by the amplitude of a signal reflecting from lateral areas of cold weld, that is with the help of an angle transducer. In this case, an error of the measurement of h by signal amplitude is more essential (for thin-wall parts it can reach up to 25 – 80%). The table shows schematic ultrasonic images of welded butt with backing strap. These images represent, in fact, a catalogue for quality estimation of weld joints with backing strap. Using these ultrasonic images, an NTD inspector can identify a defect rather quickly, thus his task becomes much simpler. Besides, the human factor (depending on NTD skill) is practically eliminated. It is not difficult to create the similar catalogues of ultrasonic images for any other construction of weld joints.

The size of defects detected with the help of ultrasonic images makes 0.12 mm and higher. The introscopes are intended for automatic tests of weld joints of different parts.