A COMPARATIVE STUDY ON DESIGN AND MANUFACTURE OF ULTRASONIC IMMERSION TESTING FIXTURE

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Abstract In this paper an effort has been made to study comparatively the existing ultrasonic immersion-testing fixture with the newly designed and manufactured ultrasonic immersion-testing fixture. The comparisons are made from the design, manufacturing and operational point of views. Finally it is concluded that the operational performance as well as the accuracy of the measurement achieved in the new fixture is far better than that of the existing one. In the existing ultrasonic immersion-testing fixture, scanning over the test specimen is done by the "X-Y" bridge type scanner. The bridge is positioned on the scanning tank and the specimen is immersed into the water. But both these X and Y-axes movement are not accurate because there is always a chance of displacement of wheels at the time of experiment. To overcome these difficulties testing fixture with rack and pinion arrangement is made. Here the total fixture is attached to the tank. The X and Y axis movement is given by rack and pinion so that high accuracy may be obtained during the detection of material flaws. In this case percentage error during measuring the depth and length of the material flaw is much lesser than that with the existing one.

Keywords: Ultrasonic immersion testing fixture, Comparative study, Material flaws, Accuracy of measurement.

INTRODUCTION

To overcome certain limitations in manual contact ultrasonic testing and to introduce various new capabilities, automatic and semiautomatic ultrasonic immersion tests are being increasingly used now. Apart from overcoming these limitations, the ultrasonic immersion testing system have many advantages and can handle the parts being inspected, segregate them as acceptable or rejected, can log the high volume test data and can generate test reports as and when required.

In ultrasonic immersion testing, the test specimen and special type leak proof transducer are immersed in a liquid usually water. The waves from the transducer enter the specimen after traveling a distance through the liquid medium. Since the probe does not make contact with the test specimen, higher frequencies can be employed.

DESIGN AND FABRICATION

In the existing ultrasonic immersion-testing fixture, scanning over the test piece is done by the "X-Y" bridge type scanner. The bridge is positioned on the tank and test piece is immersed in water. The search unit (transducer) is held at the end of a scanning tube. This tube is attached to a manipulator, which permits the controlled movement of the tube in any direction and also positions the scanning tube above the test specimen. The manipulator is attached to a traversing plate which, moves on the guide bars in transverse direction (Y-direction) by nut and screw arrangement. The traversing plate and guide bars are fitted to the wall plates which, are fitted with wheels and axles at the bottom. These facilitates the free movement of the fixture in the X-direction.

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But at the time of movement in the Y-direction by screw and nut arrangement, the wheels on the walls of the tank may roll-on thus changing the position of the fixture. Also the weight of the fixture is heavy. The fixture designed for the present study takes care of the shortcomings of the existing one.

DESIGN OF THE FIXTURE

The fixture has been designed for flaw detection on up to 300 mm long, 200 mm wide and 100mm deep aluminum and steel specimens (Fig. 5).

Scanning tank

The length and the width of the scanning tank are to be chosen according to the length and the width of the specimens. In this case the length has been chosen as

400mm and the width as 300mm. Considering the thickness of the test specimen, thickness of the stand, near zone effect (Table 8)and some clearance, the depth of the tank has been taken as 250mm. Perspex sheets have been used for making the tank because it is light in weight, transparent, easy to handle and does not react with water.

Manipulator
It provides angular movement of the scanning tube about X and Y - axes and also the vertical movement of the tube to adjust the distance between the probe and the test specimen. It consists of a) Manipulator bar b) Inside solid cylinder and c) outside hollow cylinder. The material for manipulator is Nylon.

Search unit holder and scanning tube
Two different search unit holders have been made for two transducers of different size. The search unit holder is like a collet. The probe or transducer is pushed into it and a nut holds it tightly. The material used is nylon.

Scanning tube is a long tube of nylon. Search unit holder is fitted with the scanning tube, which is attached to manipulator.

Carriage and cross-slide [Fig. 1(a) & 1(b)]
It is the most important part of the fixture. It is the part that gives the parallel and cross movement (X and Y direction movement). It gives smooth and linear movement of the transducer over the test specimen. The carriage is fitted with the tank and the cross-slide is fitted with the carriage perpendicularly. Both of them have a male and a female part. Racks have been made over the length of the male parts. Vernier scales have been made over the length for accurate measurement. The material for carriage and cross-slide is brass.

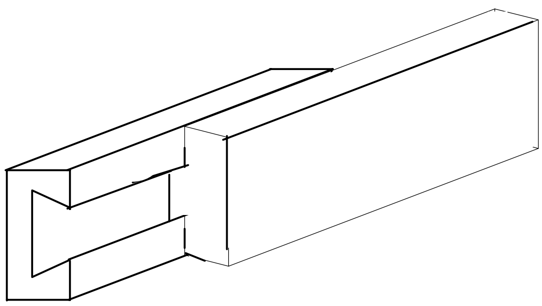

Fig. 1 (a) Carriage

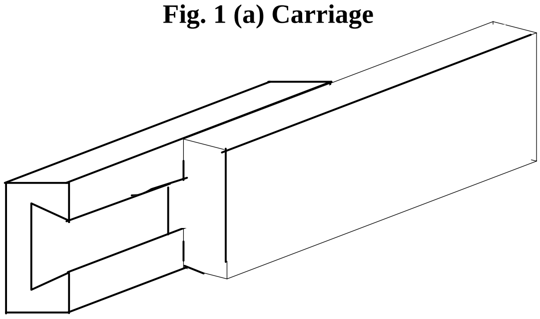

Fig. 1 (b) Cross slide

Pinion (Fig. 2)
It is important from the point of view that it meshes with the racks of the carriage and cross-slide and gives motion to them which in turn moves the probe. Helical pinions have been made here. The material for pinion is steel.

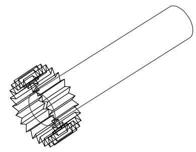

Fig. 2 Pinion with shaft

EXPERIMENTATION

An ultrasonic flaw detector has been used for the experiment. Apart from this 2.5m long coaxial cable with BNC connectors on either side, PZT probes of 5 MHz and 2.5 MHz both 10mm diameter has been used.

Steps followed for the experimentation
Scanning tank is filled with water up to required level and it is leveled horizontally.

The probe, connected to one end of the coaxial cable, is fitted in the probe holder which is fitted in the scanning tube. Then the scanning tube is attached to the manipulator. The other end of the cable is connected to the ultrasonic flaw detector. The probe is immersed into the water.

The specimen to be tested is immersed in water and placed under the probe.

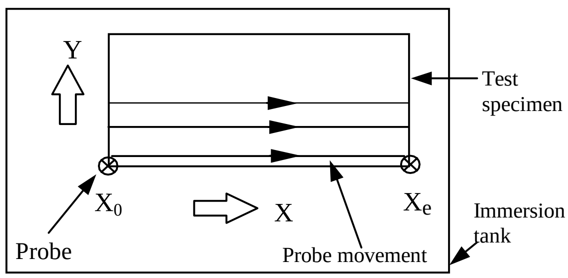

Fig. 3 Experimental procedure

Ultrasonic flaw detector is switched on and initial pulse is seen on CRT screen. By adjusting the gain and the delay and range controls, the front surface echo is obtained on the CRT screen. Manipulator is adjusted in such a way that the front surface echo amplitude attains maximum, which indicates that the ultrasonic beam is incident at normal to the test surface. Then the first back wall echo is obtained on the CRT screen. Then the test specimen is scanned in X and Y direction till the whole area of the test specimen is scanned (Fig.3). When a discontinuity is encountered, discontinuity echo is appeared on the CRT screen between front surface echo and first back wall echo [Fig. 4(b)]. Maximizing the discontinuity echo amplitude, the X-position of the discontinuity is noted with respect to the edge of the specimen.

Depth of the discontinuity from the test surface is noted on the horizontal axis (time trace) with respect to the front surface echo.

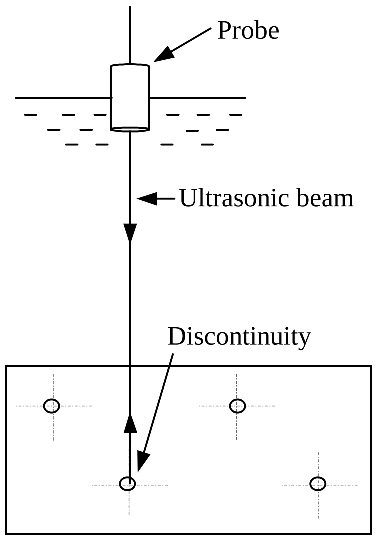

Fig. 4 (a) Detection of flaws

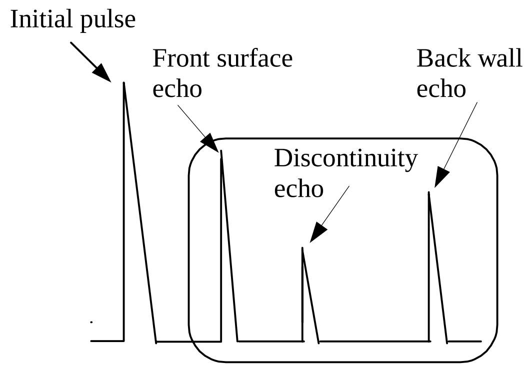

Fig. 4 (b) Echoes on CRT screen

To find the length of a particular discontinuity, the probe is positioned over the discontinuity. Then the probe is moved in the Y- direction from one end of the discontinuity to the other. Y co-ordinates of the discontinuity ends are noted by taking half amplitude fall of echo.

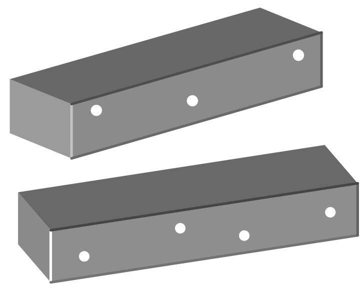

Fig. 5 Aluminium specimens

RESULTS

Table –1 Geometrical Details of Aluminium Specimen (Specimen No. 1)

Discontinuity No.	Distance from left(mm.)	Distance from top(mm.)	Length of the discontinuity(mm.)
1.	22	20	12
2.	42	30	12
3.	67	25	12
4.	80	30	12

Table –2 Experimental Results (With New Set-Up)

Discontinuity no.	Distance from left(mm.)/ % deviation	Distance from top(mm.)/% deviation	Length of the discontinuity(mm.)/ %deviation
1.	22.1/0.45	20.1/0.50	12.0/0
2.	42.1/0.24	29.8/0.67	12.1/0.83
3.	67.2/0.30	25.1/0.40	11.9/0.83
4.	80.5/0.63	29.8/0.67	12.0/0

Table –3 Experimental Results (Existing Set-Up)

Discontinuity no.	Distance from left(mm.)/ % deviation	Distance from top(mm.)/% deviation	Length of the discontinuity(mm.)/ %deviation
1.	20.1/8.64	18.5/7.5	5.0/58.33
2.	43.7/4.05	28.1/6.33	8.0/33.33
3.	65.1/2.83	23.1/7.6	7.0/41.67
4.	78.0/2.5	28.3/5.67	8.0/33.33

Table –4 Geometrical Details of Aluminium Specimen (Specimen No. 2)

Discontinuity no.	Distance from left(mm.)	Distance from top(mm.)	Length of the discontinuity(mm.)
1.	10.0	30.0	15.0
2.	14.0	23.0	15.0
3.	22.3	8.0	15.0

Table –5 Experimental Results (New Set-Up)

Discontinuity no.	Distance from left(mm.)/% deviation	Distance from top(mm.)/% deviation	Length of the discontinuity(mm.)/%deviation
1.	10.1/1	30.1/0.33	14.9 /0.67
2.	14.1/0.71	22.8/0.87	14.9/0.67
3.	22.5/0.9	8.1/1.25	15.1/0.67

Table –6 Experimental Results (Existing Set-Up)

Discontinuity no.	Distance from left(mm.) / % deviation	Distance from top(mm.)/% deviation	Length of the discontinuity(mm.)/%deviation
1.	10.4 / 4.0	30.7 / 2.33	6.0 / 60.0
2.	14.7 / 5.0	22.0 / 4.35	7.0 / 53.33
3.	23.1 / 3.59	7.3 / 8.75	10.0 / 33.33

Table –7 Velocity and acoustic impedance

Material	Velocity (m /s)		Acoustic impedance (gm/cm^2-sec)
	Longitudinal	Shear	
Aluminium	6320	3080	17
Iron (Steel)	5900	3230	46.5
S. Steel (302)	5660	3120	45.5
S. Steel (410)	7390	2990	56.7
Cast iron	3500-5600	2200-3200	25-40
Copper	4700	2260	42
Brass	3830	2050	33
Nickel	5630	2960	50
Perspex	2730	1430	3.2
Water	1483	--	1.5
Oil	1410	--	1.12

Table –8 Near field length in water

Frequency (MHz.)	Near field length (mm)	
	Φ 10 mm	Φ 20 mm
1	16.857	67.43
1.25	21.072	84.286
1.5	25.286	101.146
2	33.715	134.861
2.5	42.144	168.577
4	67.43	269.72
5	84.28	337.154

DISCUSSION AND CONCLUSION

With the existing set-up the experimental results obtained is not accurate, because there is always a chance of displacement of wheels those move on the wall of the tank. Also the scale used for measurement is ordinary one which is not suitable for this kind of precession work.

To overcome these difficulties the new set-up with rack and pinion arrangement has been manufactured.

Here the Vernier scale has been used for measurement. The movement of the probe (transducer) is very smooth for rack and pinion. So the accurate measurement can be achieved. Therefore the percentage error in measuring the position or length of the flaw is minimized. Also the most of the parts have been manufactured from nylon which reduces the total weight of the fixture. Also larger size specimen can be used here.

FUTURE SCOPE

The immersion-testing fixture designed and fabricated is manually operated. It can be automated by fixing drive mechanisms for moving the carriage in X-direction while the movement of the cross-slide in Y-direction may also be automated. Adjustable brackets and turntables can be provided at the bottom for supporting test pieces. Then the whole operation of instrument can be controlled by a computer which stores the information and produces test results as and when required.

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