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ON THE CALIBRATION OF ULTRASONIC FLAW DETECTOR

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ABSTRACT

For the assessment performance of the ultrasonic flaw detector (UFD) equipment, various standard documents are referred to such as ASTM (E-317), British Standard (BS-4331), Bureau of Indian Standard (IS-12666), and more. The methods of calibration are spelt in different tone in these documents while broadly serving the same purpose.

In the present paper a comparison for the calibration procedure for evaluation the performance of UFD for different parameters are given. NPL as a National Measuring Institute of India is providing the facility for the calibration of ultrasonic flaw detectors according to the different procedures on request from the users. Study has been made to analyse the different procedures and the most suitable calibration procedure is suggested in the present work, while keeping the essentials of recommended procedure in the standard.

INTRODUCTION

International compatibility requires that instruments made at different factories are first inspected for quality control, depending upon its ultimate application and end use. Every instrument however must comply with two very important criteria. It must be easy to use and that it must give reproducible results within certain limits of accuracy. The former is taken care of by sensible design. The later is difficult to achieve and can be by a hierarchy of calibration steps traceable to national and international measurement standards through an unbroken chain. i.e. International Standard (BIPM) - National Standard (NPL) - Transfer Standard - Secondary Standard (States) -Working Standards (inspectors) - Commercial Measures. The chain of traceability, extending from the national standard down to the end user should be applied to all users of the instruments. Hence the instruments must be calibrated and verified by an accredited and nationally

approved laboratory regularly so that measurements made in any factory are traceable to the standard and hence do not differ with measurement made elsewhere. We will discuss the calibration procedure of the Ultrasonic Flaw Detector, which is commonly used in the industries for nondestructive testing and evaluation, in the following section of the paper.

Under the national acceredation board of laboratories (NABL), NPL is coordinating the program of accreditation of calibration laboratories. This program provides technical support and critical measurement control for Quality System Certification under ISO-9000/ IS-17025.

Ultrasonic Group at NPL is maintaining and updating the primary standards, does calibration, testing and evaluation of equipment used in ultrasonic NDT. In the present paper procedures given in standards[1-8] (British Standards BS 4331, Indian Standards IS-12666, ASTM-E- 317 and E-1324) are studied and compared. The standards are referred for testing and calibration of UFD equipment.

CALIBRATION OF ULTRASONIC FLAW DETECTION SYSTEM.

Calibration involves evaluation of some parameters of the equipment and comparing these with the standard available in the standards maintaining institute at national level. The ultrasonic Flaw detection system comprises of an ultrasonic Pulse echo system (UFD), transducer, interconnecting cables and couplant. Ultrasonic response from appropriate test block [2,6] is obtained and presented in the numerical for the test data are used to characterise the related system parameters in accordance with users requirement.

Various parameters generally measured or calibrated are as follows.

1. Linearity of time base or horizontal linearity
2. Linearity of equipment gain or vertical linearity
3. Sensitivity and Signal to noise ratio
4. Penetrating Power
5. Resolving Power
6. Operating frequency
7. Transmitter pulse Characteristics
8. Gates, range of gate width & delay
9. Variation in power supply

For measurement of some of these parameters, different procedures are given in different standard procedures written in the standards. British Standards has elaborately explained and written the procedures in three different parts. American Society of Testing Materials (ASTM) standard has written different standards for electronic characteristics and pulse echo test system without electronic measurement of instrument. Indian standard specify only ultrasonic flaw detection system and not the electronic characteristics of excitation pulse of UFD. Whereas the calibration or performance of the equipment depends on the characteristics of excitation pulse of UFD, receiving signal characteristics,

amplifiers, transducer and cable characteristics and the reference standards blocks used for measuring the characteristics. The table 1. shows parameters and procedures for their measurement in brief.

TABLE

Parameters	Procedure of measurement
Horizontal linearity	
Indian Standards :	Using IIW V1 or A2 block time base is adjusted for multiple echo pattern display. Range is set or calibrated for 100 or 500mm for at least two of bottom echoes, first and last. Then intermediate echoes should line up with appropriate positions. Intervals between leading edges of successive bottom echoes are measured and their deviation (a max) with respect to graticule is recorded. If b is the full scale of time base linearity is given as (a max / 0.8b)100%
British Standards :	Using IIW V1 / A2 block range is set separately for L-wave and S-wave probes. Carefully manipulate the probe to maximise the chosen signal and set 1st echo at zero and last echo at the 10th graticule mark. When correct spacing of echo established, the accuracy of intermediate range will depend on linearity. Accuracy should be ± 2% or better of total range set.
ASTM :	Use appropriate block and receive noninterfering back echoes. Set reflections at 50% of full scale (FS) for its position measurement. Set position of 3rd and 9th signals at 20% and 80% of scale divisions. Read and record scale position of each other multiple. Data are plotted.
NPL :	Similar to IS
Vertical Linearity	
Indian Standards :	Using A2 block range is set for 250mm or 500 mm. 10 or 5 multiple echoes are observed respectively. Gain is set to obtain all the echoes (10 or 5). Height of echo is recorded (h1) and gain is set and recorded to obtain echo height (h2) for 50 % of original scale. Deviation of nonlinearity more than ± 5% is not permissible.
British Standards :	Obtain reflected signal from 1.5mm dia in standards block. Set the signal 80% of FS. Note the value of calibrated gain control in dB. Increase gain by 2 dB. Signal should increase to 100% FS. From initial setting decrease gain by 6 dB. The signal should be 40% FS. Reducing further 12 db, signal should be 10% FS. Reducing further 6 dB, signal should be 5% FS.
ASTM :	Two methods are given , Method (A) - Two signal ratio technique. Using test block echoes amplitude of two signals HA and HB is set

in ratio of 2 to 1. These are compared by varying the gain of the instrument. Preferred and acceptable values are given in a table. The ratio should be 2±0.2, data are plotted to see V-linearity.

Method (B) - Input output attenuator technique. 30 dB external attenuator is used as in given figure . Adjust gain and sweep to produce center screen deflection 50% FS. Now decrease external attenuation in 1 dB steps until FS deflection is reached. Record signal amplitude in % of FS. Repeat process for 2 dB and 4 dB steps of external attenuator. Table is given to see optional values and data are plotted as an example.

NPL Using A2 block multiple echoes display is set for 10 echoes. Amplifier gain control reading is read. Now for 6 dB down gan height of signal is observed it should be 50 % of the former for all the 10 echoes respectively. The deviation more the ±5% is not permissible.

Sensitivity and Signal to Noise Ratio

British Standard : Set noise suppression control(Reject) to zero, set backwall echo to 20% FS measure attenuator reading. Now adjust attenuator until noise reaches the same height and measure. Difference in two readings in dB will give signal to noise ratio.

ASTM : The sensitivity is given by smallest hole size giving indication of amplitude 60% FS or more. Also noise should not exceed 20% FS

NPL : Similar to BS

Resolving Power

Indian Standard : Depend both on probe and UFD. Axial resolving power is assessed if echo signals from two steps of 85 and 91mm in A2 block is clearly separated at lease up to 6dB below maximum echo height. Lateral resolution is checked using maximum echo height from hele at distance R of block and then shifting (d) sideways till echo drops by TDB lateral resolution is given by then d/R. A7 block is designed for resolution check.

British Standard Resolving power is given by (d/R) and measuring probe shift (d) and range (R)

ASTM Resolution for entry surface and far surface is determined. Selection made on test required for the block, frequency and transducers. Interface signal is maximised by alignment of search unit. A hole should be resolved if its indication is separated from interface down to at least 20% FS and if there is no residual indication greater than 20% FS. Uses different test blocks.

NPL Similar to IS

Operating frequency

Indian Standard : For accurate measurement of frequency of instrument, calibrated spectrum analyser has to be used otherwise unrectified signal of

UFD (or an additional calibrated oscilloscope) reflected from A2 block is used for frequency measurement. The time scale be calibrated to give 5us at full screen width. Number of cycles observed divided by time interval of pulse gives frequency of operation.

British Standard — Similar as in IS

ASTM — Pulse frequency spectrum for tuned or unturned pulses at maximum and minimum damping is taken for peak frequency and operating frequency.

NPL — Similar as in IS. Also by taking FFT of the echo signal frequency band width is measured

Transmitter pulse Characteristics

British Standard and — Effective output impedance measured for both at double probe single probe position without probe. Open circuit EMF is measured on a calibrated oscilloscope (V1). Potential difference (V2) is measured across a termination resistor usually 50 or 75 ohm. Then effective output impedance is R(V1-V2)/V2.
Pulse repetition frequency is measured with PRF control set at maximum and minimum. Pulse amplitude, pulse shape is measured on a calibrated oscilloscope. Rise time, the maximum interval between the pulse position at 10% and 90% of its peak amplitude, measured in microsecond. Pulse duration, interval between pulse position at 10% of its peak amplitude measured in calibrated oscilloscope.

ASTM — In power supply section, measurement, line voltage regulation is checked. Discharge and charge time measured for battery operated instruments. In pulser section, pulse shape (either narrow or broad band) is measured and plotted. Pulse rise time, duration and amplitude is measured. Rise time is interval between 10% and 90% point of peak amplitude. Measurements are made using calibrated oscilloscope and with and without a 50 ohm termination resistor.

NPL — Similar as in BS

Gates, Range of gate width & delay

British Standard — Pulse generator is used to measure the gate delay range. Set the delay to minimum and pulse generator aligned the displayed pulse with leading edge of gate and repeated for gate delay set to maximum. Gate width minimum and maximum is also measured using pulse generator.

ASTM — Maximum and minimum delay and width of the gate are measured respectively. Operation of alarm for minimum and maximum of width is checked.

NPL Similar as in BS

Probe index, probe or beam angle, beam profile, beam alignment (SQUINT), dead zone and near and far fields are the characterisation of probes. These depends on the probes only. Therefore procedures for measurement is not given here. However penetration and resolving power, depends on probes as well as UFD instrument and depends on the frequency of probe and operating frequency strongly. Sensitivity and signal to noise ratio also depends on the characteristics of both UFD instrument and that of probe.

NPL is having facilities to measure the parameters according to desired standards and on the reques from user. But the procedure we found most suited is stated as int he given table for a particular parameter.

CONCLUSION

From the study it is observed that characteristics of ultrasonic flaw detector or pulse echo test instrument influence the test results. Performance of the system depends on various electronic characteristic of instrument, transducer characteristics, couplant, cables and material under test, more or less BS and ASTM standards states the procedures for measuring characteristics of transmitter pulse of the UFD. Procedure for receiving signal characteristics is given in all the three Standards. They gives information about the linearity of time base and amplifier gain of the system. Transducer characteristic can be Measured using IS or BS both. IS requires further additions in the procedures for measuring transmitter characteristics and modifications in receiver characteristics to make them simpler and informative. NPL has the facilities for performance evaluation of the system using the required calibrated instruments, traceable to National Standard. Number of calibration reports have been prepared at NPL. Reports are prepared using most of the standard procedures on the request of user.

REFERENCE

1. IS12666: 1998,Indian Standard, Methods for performance assessment of ultrasonic flaw detection equipment.
2. IS 4904, Indian Standard, Calibration block for evaluation of Ultrasonic flaw detection equipment.
3. BS 4331- Part I, British Standard, Methods for assessing the performance characteristics of ultrasonic flaw detection equipment. (Part-1. overall performance)
4. BS-4331- Part-2, British Standard, Methods for assessing the performance characteristics of ultrasonic flaw detection equipment. (Part-2. Electrical Performance)
5. BS-4331 Part-3, British Standard, Methods for assessing the performance characteristics of ultrasonic flaw detection equipment. (Part-3. Guidance for the in service monitoring of probes)

6. BS-2704, British standard, Specification for calibration blocks for use in ultrasonic flaw detection.
7. E-317 ASTM Standard, Standard practice for evaluating performance characteristics of ultrasonic pulse echo testing system without the use of electronic measurement instruments.
8. E-1324, ASTM standard, Standard guide for measuring some electronic characteristics of ultrasonic examination instruments.