



CORPORATE STANDARD

AA 085 01 01

Rev. No. 02

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NON-DESTRUCTIVE TESTING PROCEDURES AND ACCEPTANCE STANDARDS FOR SHAFT FORGINGS OF HYDRO-TURBINES AND HYDRO-GENERATORS

1.0 GENERAL :

This standard deals with ultrasonic and magnetic particle testing procedures and acceptance standards for shaft forgings of hydro-turbines and hydro-generators.

2.0 PERSONNEL REQUIREMENT:

Personnel performing non-destructive examination and evaluation shall be qualified to the recommended practice SNT-TC-1A or any other recognised practice.

3.0 SURFACE CONDITION:

The surface of the rotor shall be machined to a finish of 6.25 microns or better for ultrasonic testing. A gramophone record type of finish or tear produced by machining tools shall be avoided, since these give rise to spurious echoes and cause probe wear. The bore of the rotor shall have a finish of 3.2 microns for the purpose of boroscopic examinations.

4.0 ULTRASONIC TESTING:

4.1 Equipment Characteristics:

4.1.1 Frequency Range:

The ultrasonic equipment shall be suitable for operating at frequencies within the range of 1 to 6 MHz.

4.1.2 Sensitivity:

The sensitivity of equipment shall be tested to ensure that the number of full screen back wall echoes is not less than that given below, when the appropriate probe is placed on the metallised surface of plastic insert of Indian standard reference block (IS:4904) or IIW block.

<u>Frequency range, MHz</u>	<u>Min. No. of full screen back wall echoes</u>
1.0 to 1.3	5
1.4 to 1.8	4
1.9 to 2.6	3
2.7 to 6.0	2

Revisions :

Cl 15.8.2 of MOM of WG-NDT

APPROVED :

INTERPLANT STANDARDIZATION
COMMITTEE - (WG-NDT)

Rev. No.02	Amd.No.	Reaffirmed	Prepared	Issued	Dt. of 1 st Issue
Dt:15.01.2002	Dt :	Year :	RHOPAL	Corp. R&D	Sep. '87

**4.1.3 Resolution:**

The resolution of the equipment and probe combined shall be such as to show separately, indications from two or more nearby reflecting surfaces when the difference in beam path lengths between them does not exceed twice the wave length.

4.2 Couplant:

To ensure adequate transmission of ultrasonic energy between the probe and the test object, a suitable couplant having good wetting characteristics such as oil, grease, water, glycerine or cellulose paste shall be used.

4.3 Testing Technique:

A pulse-echo direct contact flaw detection technique shall be followed. Testing Technique should be such that each and every part of the object volume is scanned at least once. Successive scans shall overlap a minimum of 15% of the probe width. Uniform contact shall be maintained between the probe and the object and scanning speed shall not exceed 150 mm/second. Complete length of the forging shall be scanned radially from the cylindrical surface through 360° using longitudinal wave probe. Whenever practicable, the forging shall be scanned in axial direction also. When necessary, forging shall also be scanned using appropriate shear wave probes to detect axial and radial cracks.

4.4 Scanning:**4.4.1 Probes And Frequency:**

Overall scanning shall be done using 2-4 MHz, 20-25 mm diameter probes. Higher frequency and smaller size probes may be used when found necessary.

4.4.2 Time Base Calibration:

The time base shall be calibrated using a calibration block or a known dimension of the forging under examination.

4.4.3 Sensitivity:

The sensitivity of the equipment during scanning shall be set 6dB more than the sensitivity required to give a full screen height echo from the maximum acceptable size of defect.

NOTE:- The above sensitivity level adjustment is purely for scanning purposes. Once, a defect is encountered, the sensitivity shall be brought down to estimate the size of the defect for evaluation of the material under test.

4.5 Estimation Of Flaw Size:**4.5.1 Large Size Flaws:**

The size of large flaws can be estimated by moving the probe in all directions and plotting the mid-point of probe when echo falls to 50 percent or 6dB.

**4.5.2 Small Size Flaws:**

The size of flaw (smaller than the beam spread) can be estimated accurately in millimetres of equivalent circular flaws with the help of DGS (Distance-gain-size) Scales/DGS diagrams. Wherever DGS scales are available the equivalent flaw size shall be estimated using appropriate DGS scale for the probe and test range used. Otherwise, a DGS diagram shall be used for this purpose. Method of estimating flaw size using DGS diagram is given in Annexure-A.

4.6 Acceptance Standards:

The following defects shall be unacceptable:

- i) Cracks, flakes, seams and laps.
- ii) Defects giving indications larger than that from a 4 mm diameter equivalent flaw.
- iii) Groups of defects with maximum indication less than that from a 4 mm diameter equivalent flaw which can not be separated at testing sensitivity if the back echo is reduced to less than 50%.
- iv) Defects giving indications of 2 to 4 mm diameter equivalent flaw separated by a distance less than four times the size of the larger of the adjacent flaws.
- v) Defects giving "Travelling" indications indicative of radial orientation.
- vi) Loss of back wall echo by more than 50% even if there is no defect indication.

4.7 Attenuation Measurement:

After final heat treatment, attenuation readings shall be taken at three equally spaced circumferential positions at both ends and the middle of the rotor body in the following manner. Set the first back wall echo at 40 mm and record the calibrated attenuator reading. then set the second back wall echo at 40 mm and again record the calibrated attenuator reading. The difference between these two readings shall be recorded. These readings shall be made at both 2 and 4 MHz. If values greater than 20 dB are recorded at either frequency, this shall be brought to the attention of BHEL for further investigation before the forging can be accepted.

5.0 MAGNETIC PARTICLE TESTING:

5.1 All magnetic particle flaw detection shall be carried out in accordance with the requirements of ASTM E 709 at final inspection stage.

5.2 Shaft Bores:

Where there is axial bore in the shaft, the complete bore surface



shall be subjected to Magnetic Particle Testing. The magnetic field shall be produced by passing direct current or full wave or half wave rectified alternating current through a conductor threaded longi-tudinally through the bore. The field strength used shall comply with that laid down in ASTM E 709.

The continuous method whereby magnetic particles are applied while magnetisation continues, shall be used wherever possible. Otherwise by agreement with BHEL, the residual method may be applied using direct current magnetisation.

The bore shall then be examined with a suitable boroscope giving a magnification of X2 to X4 and assessed in accordance with clause 5.4 of this document. The rotor shall then be half turned, the bore cleaned out, re-magnetised, re-sprayed and examined with the boroscope.

On completion of the examination, the bore shall be cleaned and the forging shall be free from residual magnetism prior to despatch.

5.3 Shaft External Surfaces:

All re-entrant changes in section present at the normalising and tempering stages of manufacture shall be subjected to magnetic particle inspection for detection of circumferential and longitudinal cracks.

5.4 Acceptance Standards:

The following defects shall be un-acceptable:

- i) Cracks / linear defects.
- ii) Inclusions larger than 3 mm.
- iii) Groups of inclusions within which individual defects exceed 3 mm length.
- iv) Dispersed inclusions exceeding 2 in any 150 mm length of bore.

Note: A group is defined as any number of defects separated by less than 2X length of the longest. In case of defects in the same plane, separated by less than 2X the longest, they shall be regarded as a single defect of length equal to the overall length of the group.

ANNEXURE - A (Clause 4.5.2)

DGS DIAGRAM

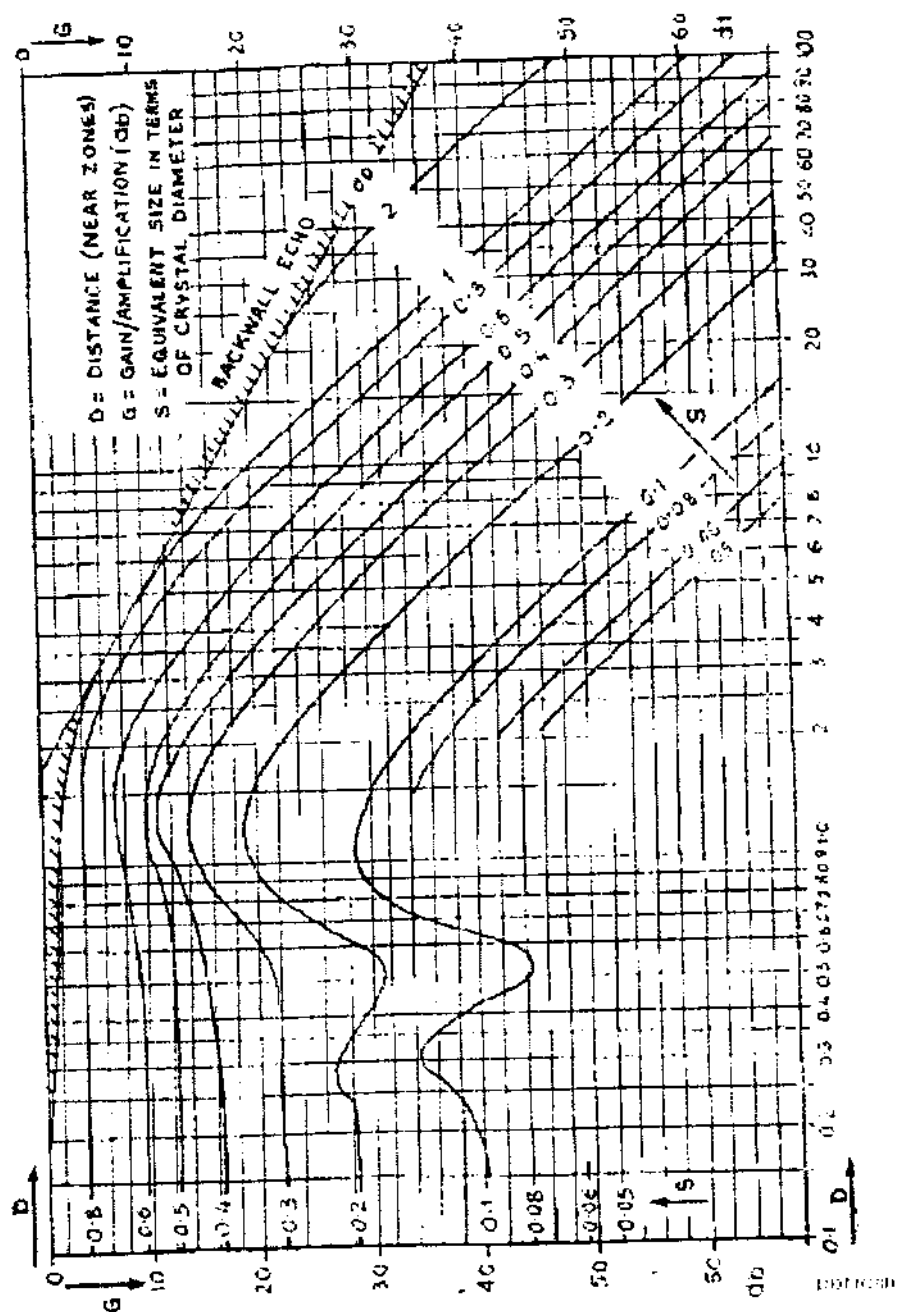
The equivalent flaw size curves of DGS diagram is prepared by plotting the amplitude in decibels from a series of circular reflectors with increasing distance from the probe in water and so the graph incorporates only the loss in water. When it is found that the attenuation in the material under test is more (this can be checked using back echo curve of DGS diagram) this shall be taken into account while calculating the flaw size. Corrections will not be required for majority of heat treated forgings when tested with 2- 4 MHz probes.



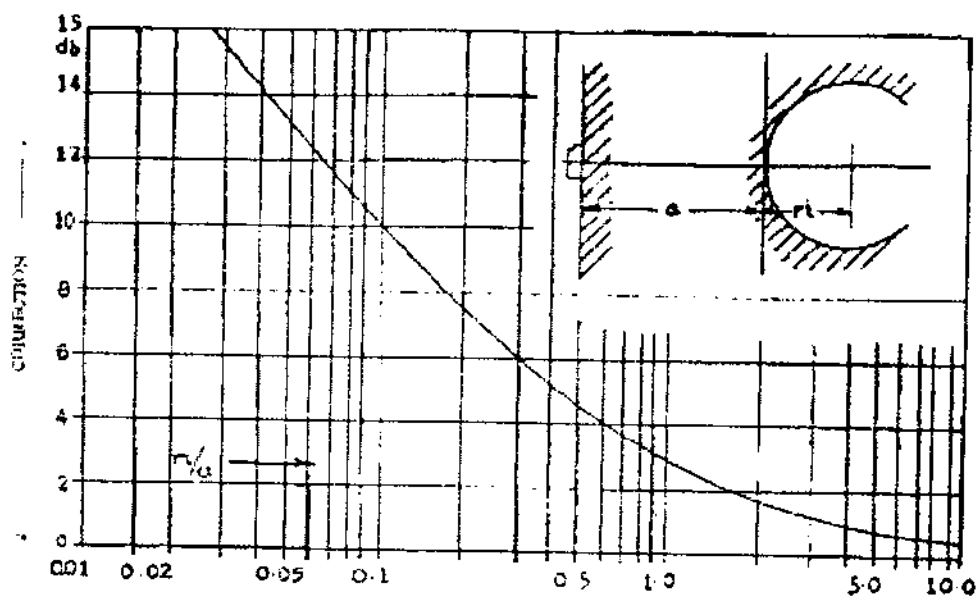
A step by step method of estimating flaw size using universal DGS diagram shown in Fig.1. is as given below:

- a) Adjust the depth range of the equipment to the required depth.
- b) Adjust the back echo to 70% screen height from a defect free area parallel wall of the material under test or ultrasonically similar test block and note the dB value (A) on the calibrated gain control.
- c) Mark on the back echo curve of the diagram, the back wall distance in terms of near-field in millimetres in the case of universal DGS diagram.
- d) Move the probe to the defective area and get the maximum defect echo. Read off the flaw depth. Increase the gain with the calibrated gain control until echo height reaches 70 percent of screen height. Note the attenuator reading in dB (B).
- e) Calculate the gain (G-1) in dB by subtracting 'A' from 'B'. Refer Fig. 2 and obtain the correction factor (F). Calculate gain (G-2) in dB by subtracting 'F' from G-1.
- f) Count off the gain G-2 downwards from the marked point on the back wall echo curve and then move horizontally to intersect the vertical line from the base line. corresponding to the flaw depth 'D' in terms of near-field in case of universal diagram.
- g) Note the equivalent flaw size curve passing through the above point. Multiply the reduced flaw dimensions (S) of the curve by the probe diameter to give the equivalent flaw size in mm.

APPENDIX - A (Contd.)

FIGURE 1
DGS DIAGRAM

ANNEXURE - A (Contd.)



CORRECTION FOR CURVED BACKWALL
FIGTUR - 2