Penetrameter (RT) and V1 Block (UT): Engineering Marvel

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Abstract

All NDT methods are basically comprises of five essential features. They are 1.Basic Principle;2..Artificial Defect;3.Probing Media; 4.Testing Media and 5.Recording Media. Among them the most important is the artificial defect. In any NDT method, it has been practiced that, from the known artificial defect to detect the unknown natural defects in the test objects. Artificial defects are representing the specific NDT method's ability to reveal flaws or thickness changes in the specimen being examined.

In Radiographic Testing the Penetrameter and in Ultrasonic Testing, the V1 block are demonstrating the engineering marvel in both design and representing the generalization of actual defects nature associated with the test parts. For most NDT practitioners, the Penetrameters are used for the purpose of checking sensitivity and technique in Radiographic Testing and the V1 block for the purpose of calibration and range setting in Ultrasonic Testing. But both the Penetrameter and the V1 block capable of demonstrating how a same defect behave in different manner according to the basic principle of RT and UT and others as well.

Keywords: Radiographic Testing, Ultrasonic Testing, artificial defect, penetrameter and V1 block

Introduction

This paper provides a description of the artificial defects used in Radiographic and Ultrasonic testing, after a brief review about NDT and the test methods RT and UT.Welding is widely used in the fabrication of nearly all industrial components.Despite the best care taken during design, fabrication and inspection, many of the weld components fail especially at the weld and heat affected zones,drastically influencing the performance reliability and component availability.Majority of the failures are attributed to improper design of weld joint,selection of base materials and filler materials,welding processes,residual stresses,inspection procedures and operating parameters.One way to minimise the failures of welded components is to impart NDT procedures:1.make sure defect free welded joint and 2.ensure unacceptable defects are present and grow during the component in service.

Objective of NDT Method

Even small defects can be troublesome with potential to generate accidents and injuries, besides causing the customers unsatisfaction. To detect such failures special inspection methods are necessary.

A variety of NDT techniques are available for detection and charaecterization of defects in welds.All NDT techniques are based on physical principles.Nearly every form of energy is used as probing medium in NDT.Each NDT method is to provide information about the following parameters, like discontinuities,structure or malstructure,dimension and metrology,physical and mechanical properties, composition and chemical analysis, stress and dynamic response and signature analysis.

Therefore, the Non-Destructive Testing (NDT) arises, defined as a method to evaluate materials, pieces, equipment or detects the failure without causing damage to the inspected element. There are different forms of NDT, such as: Eddy Current, Magnetic Particle, X-Ray, Gamma- Ray and Ultrasound.

Principal Factors of an NDT Method

As stated above, NDT is used to investigate the material integrity of the test object and is concerned in a practical way with the performance of the test piece-how long may the test piece be used and when does it need to be checked again? Each NDT method can be completely characterised in terms of five principal factors, they are:
1. Basic Principle; 2. Artificial Defect; 3.Probing Media; 4.Testing Media and
5. Recording media.

Purpose of Weld Reinforcement

The allowable weld reinforcement is made for the purpose of radiographic testing. Due to radiation absorption difference, the parent metal and the weld metal with reinforcement reason to enhance a very good subject contrast on the radiograph. If there is any discontinuity due to the reduction of metal or by the inclusion of low atomic number material in the weld volume, they are appears as a dark images over white contrasting background.

Radiographic Testing

In Radiographic Testing, we are catching the shadow of an object .Light (source), object and screen are necessary to make a shadow and also must be in the same order. Shadow formation by means of non-penetrating radiation is photo(light)graphy(recording medium) and the shadow formation by means of penetrating radiation is Radio(radiation)graphy(recording medium).However, both the penetrating (high energy) and nonpenetrating (low energy) radiations are made up of photons. In radiographic testing, the defects are represented in shadow patterns on the recording medium. RT has its uniqueness in recording the three dimensional volumnar defects, hence radiograph is the two dimensional representation of the three dimensional object.

Penetrameter

Penetrameter is an artificial defect as well as the heart of the radiographic testing. The Penetrameter was introduced early 1950s [1] API 1104 as one penetrameter of a specific thickness approximately 2% of the designated pipe wall thickness and during mid 1960s the designated one penetrameter of a specific thickness was changed for a range of pipe wall thicknesses. It is a standard test piece is usually included in every radiograph as a check on the adequacy of the radiographic technique. The test piece is commonly referred to as penetrameter in N America and an Image Quality Indicator (IQI) in Europe. It is tool to measure the contrast or change in density on an image for a known change in thickness in the specimen.

Penetrameter provides an effective check on the overall quality of the radiographic inspection. The image of the penetrameter transferring from source side of the test part to the film ensures that any defect equal and above that of the subject contrast of the penetrameter selected will be recorded on the film after crossing over the entire part thickness.

Radiation beam is divergence in nature, maximum intensity at centre and minimum intensity at the edge of the central beam. The penetrameter should be usually placed on the source side of the test part and at the edge of the central beam. This is because, Penetrameter whose image cast on the film after crossing the entire part thickness, with the minimum intensity level at the edge of the central beam, ensures that any defect covering in the area of interest of the test part will be recorded on the radiograph.

The purpose of penetrameter are: 1. Check sensitivity (refers size of a defect);2.Check technique (refers shape of a defect); and Check material identification (penetrameter without notch for carbon steel materils and with notches for other than carbon steel materials) (Figure:1).Then there are two general type of penetrameters used in Industrial Radiogarphy:1.Hole type (reduction of metal) and wire type (addition of metal). Here we are concern only hole type penetrameter.

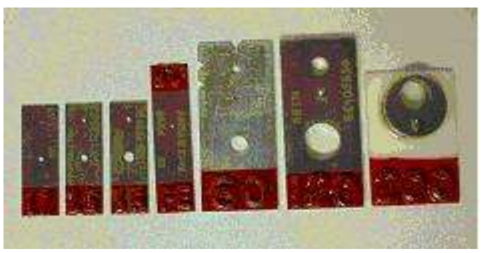

Figure:1 Penetrameters with and without notches.

Penetrameter Selection

The selection of the penetrameter is 2% thickness of the part under test.This limitation was taken based on safety consideration for any industrial metal fabrication product. For a weld of thickness below 2% of its allowable limit, the strength of weld weakened by 40%. As per safety consideration, the weld weakness above 40% not acceptable. Further the explanation goes on that the two percent penetrameter thickness and required hole sizes possibly eveolved from engineering decisions made in reference to questions such as:" What is the largest inclusuion we can afford to have in the part but not be able to find?" and " What thickness of penetrameter can be reliably seen on the film image?" As thickness of the test material increases, the size of the indication you can afford to miss also increases. Thus, a thicker penetrameter and larger required hole is specified [2].

This would supposedly guarantee that defects of a certain minimum size, expressed as a percentage of the material thickness, could be detected. In practice, however, this proved not to be achievable. In particular where small cracks and other two-dimensional defects are concerned, it can never be guaranteed that they are not in fact present when no indication of them can be found in the X-ray image. However, it is reasonable to expect that at least the quality of the radiographs, and of course the rest of the entire process the film undergoes, meets certain requirements.

Like that the energy selection and the limitation of rejection criteria based on part thickness, the Penetrameter selection also based on the nominal single wall thickness of the test part. The penetrameter either hole or wire type, they will demonstrate the basic principle of radiographic testing, as the change in differential absorption of radiation. Sensitivity determines the extent to which a radiograph is able to clearly show (anomaly)

Details of a Certain Size

Generally Hole type Penetrameters are of two different sizes (not include the circular penetrameter) and are rectangular in shape.The human eye perceives much more readily a long boundary than it does a short one are the reason for ASTM and ASME designed rectangular shape penetrameters (Figure:2). Up to 2.5 inch part thickness the Penetrameter size is 0.5inch height and 1.5 inch length and for the thickness above 2.5 inch thick, the Penetrameter size is 1inch height and 2.25inch length.

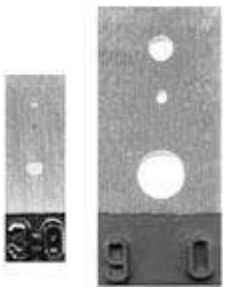

Figure:2 Two different sizes of rectangular Penetrameters

A hole type Penetrameter has two parts (Figure:3), one is defective side-the holes (sensitivity level) and other part is the thickness of the Penetrameter (subject contrast level) identified in lead numbers that are expressed in mil.(1 inch =25mm and 1inch=1000mils. Therefore 25mm=1000mils and imm=40mils). Of the three holes, the diameter of the middle one is the one times the thickness (1T hole) of the Penetrameter then to its right is two times thick (2T) and to its left is four times thick(4T)

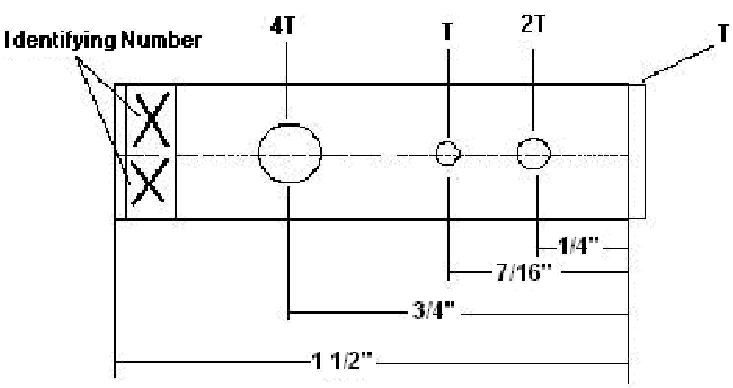

Figure:3 Peneram則eter Dimension

Penetrameter Materials

A penetrameter is made of the radiographically same material or a similar material as the specimen being radiographed and is of simple geometric form it contains some small structures (holes – reduction of metal and wires- addition of metal etc.). The dimension
of which bear some numerical relation to the thickness of the part being tested. The image of the Penetrameter and the radiograph is permanent evidence; the radiographic examination was conducted under proper conditions.

As emphasised above, the use of an IQI does not guarantee detection of defects of comparable size. It would be incorrect to say that because a hole of 2 % of the object thickness can be seen on the radiograph, a crack of similar size can also be detected. The orientation, relative to the X-ray beam, of a defect plays an important role in its discernibility.

Ideally, the penetrameter should be made of the specimen under test, however this is sometimes impossible because of practical or economic difficulties. In such cases the penetrameter may be made of radiographically similar material that is a material having same radiographic absorption as the specimen. In addition a penetrameter made of a particular material may be used in the radiography materials having radiographic absorption. Like heat energy, radiation is also one form of energy. To boil water one can use SS instead of Aluminum but never to use plastic. Like that, in case of inadequacy number of penetrameters of one group material, one can use higher atomic number material penetrameter and never to use lower atomic number. In practically all cases the penetrameter is placed on the source side of the specimen in the least advantageous geometric position.

Both the hole and outline of the penetrameter should be visible on the radiograph. Of the two dimensional representation of the image, the length and height of a three dimensional object, the hole ensures the horizontal measure of sharpness and the outline ensures the vertical measure of sharpness.

Ultrasonic Testing

UT is the subsurface (test result not recorded on the test part itself) NDT method that used to detect two dimentional planar type laminar defects (flaw detection) and thickness measurement. UT is best to locate the depth of the defect (reflector).There are four essential steps in UT.Generation of ultrasound; send into the part ; received by the probe and inspection at the CRT/ LCD monitor.

The defects are represented by means of echo pattern. The basic principle of UT is change in Acoustic Impedence [3].Acoustic means sound and impedence means the amount of sound refelection at the interface. Sound waves do not travel beyond interface, hence they reflect back at the interface. In the pulse-echo technique,in which pulse implies interval of sound transmission and receiving and echo indicates the act of sound reflection at the interface.On the monitor, the horizontal line indicates the time of flight that is path taken by the sound beam inside the test part and the amplitude of the reflected energy represented in the form of echo. In pulse-echo set up the reflected energy is depending on the distance,area and orientation of the reflector.

V1 Block

It is an artificial defect of Ultrasonic Testing. The V1 block (Figure:4) was designed by Internation Institute of Welding, that’s why the block is also familiarly known as IIW block. The block not only used for calibration purposes but a variety of other technical reasons as described below.

i) In UT The wavelength should equal or less than the detectable defect size.

ii) Reflectors may be filled with air or some other materials.

iii) The location of the defects at:
1.Surface
2.Subsurface
3.Embedded

iv)The shape of the reflector can be
1.Spherical
2.Cylindical
3.Planar

v) Artificial Refelector:
1.Notch (for Pipes)
2.Side Drilled Hole (SDH) (for Welding)
3.Flat Bottom Hole (FBH) (for Casting and Forging)

vi) Rejection Criteria
1.Reflector size less than the wavelength DGS (maximum amplitude technique) used
2.Reflector size greater than the wavelength DAC (amplitude comparison technique) used

V1 Block Dimensions are Expressed in mm.
The block length is 300mm; height is 100mm and the thickness is 25mm.

The surface notch is the representation of surface defect.

The 2mm wide notch is the representation of an embedded defect; planar in shape; kind of FBH used for casting and Forging and used for resolution check.

The through hole is the representation of subsurface defect; cylindrical in shape; kind of SDH used for artificial defect of welding and used for sensitivity check.

The 50[mm] Perspex used for penetrating power check.

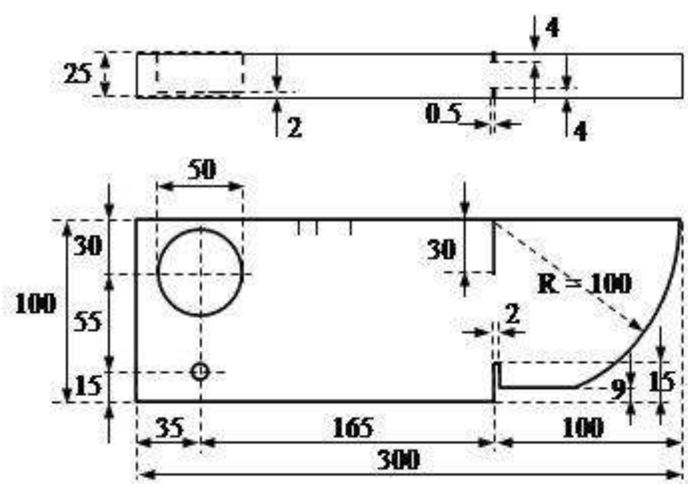

Figure:4 V1 Block Dimension.

The material of the reference standard should be the same as the material being inspected and the artificially induced flaw should closely resemble that of the actual flaw.

In ultrasonic testing, reference standards are used to establish a general level of consistency in measurements and to help interpret and quantify the information contained in the received signal. Reference standards are used to validate that the equipment and the setup provide similar results from one day to the next and that similar results are produced by different systems. Reference standards also help the inspector to estimate the size of flaws. In a pulse-echo type setup, signal strength depends on both the size of the flaw and the distance between the flaw and the transducer. The inspector can use a reference standard with an artificially induced flaw of known size and at approximately the same distance away for the transducer to produce a signal. By comparing the signal from the reference standard to that received from the actual flaw, the inspector can estimate the flaw size [4].

This second requirement is a major limitation of most standard reference samples. Most use drilled holes and notches that do not closely represent real flaws. In most cases the artificially induced defects in reference standards are better reflectors of sound energy (due to their flatter and smoother surfaces) and produce indications that are larger than those that a similar sized flaw would produce. Producing more "realistic" defects is cost prohibitive in most cases and, therefore, the inspector can only make an estimate of the flaw size.

Conclusion

Though penetrameter is a tiny device as compared with that of the test part but includes the overall essential features of the radiographic qualities, such as sensitivity, technique, density, contrast, geometric unsharpness, material identification and image enlargement. Like that in UT, the V1 block, it is not only for used for calibration and reference and also serves location, shape and behaviour pattern of different reflectors. In that way both penetrameter and V1 block are certainly the product of engineering marvel!.

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