

The need of inspection and testing of welded joints

This chapter explains the need of inspection and testing of welded joints in different stages besides two broad categories of testing of weld joints. Further, three most common destructive testing methods namely tensile, hardness and bend test also have been described.

Keywords: Stages of inspection, weld testing, quality of weld, destructive testing, tensile test, bend test, hardness test

31.1 Introduction

To produce quality weld joints, it is necessary to keep an eye on what is being done in three different stages of the welding

- Before welding such as cleaning, edge preparation, baking of electrode etc. to ensure sound and defect free weld joints
- During welding various aspects such as manipulation of heat source, selection of input parameters (pressure of oxygen and fuel gas, welding current, arc voltage, welding speed, shielding gases and electrode selection) affecting the heat input and so melting, solidification and cooling rates besides protection of the weld pool from atmospheric contamination
- After welding steps, if any, such as removal of the slag, peening, post welding treatment

Selection of optimal method and parameters of each of above steps and their execution meticulously in different stages of production of a weld joint determine the quality of the weld joint. Inspection is mainly carried out to assess ground realities in respect of progress of the work or how meticulously things are being implemented. Testing helps to: a) assess the suitability of the weld joint for a particular application and b) to take decision on whether to go ahead (with further processing or accept/reject the same) at any stage of welding and c) quantify the performance parameters related with soundness and performance of weld joints. Testing methods of the weld joint are broadly classified as destructive testing and non-destructive testing. Destructive testing methods damage the test piece to

more or less extent. The extent of damage on (destructive) tested specimens sometime can be up to complete fracture (like in tensile or fatigue testing) thus making it un-useable for the intended purpose while in case of non-destructive tested specimen the extent of damage on tested specimen is either none or negligible which does not adversely affect their usability for the intended purpose in anyways.

Weld joints are generally subjected to destructive tests such as hardness, toughness, bend and tensile test for developing the welding procedure specification and assessing the suitability of weld joint for a particular application. Visual inspection reflects the quality of external features of a weld joint such as weld bead profile indicating weld width and reinforcement, bead angle and external defects such as craters, cracks, distortion etc. only.

31.2 Destructive Test

31.2.1 Tensile test

Tensile properties of the weld joints namely yield and ultimate strength and ductility (%age elongation, %age reduction in area) can be obtained either in ambient condition or in special environment (low temperature, high temperature, corrosion etc.) depending upon the requirement of the application using tensile test which is usually conducted at constant strain rate (ranging from 0.0001 to 10000 mm/min). Tensile properties of the weld joint are obtained in two ways a) taking specimen from transverse direction of weld joint consisting base metal-heat affected zone-weld metal-heat affected zone-base metal and b) all weld metal specimen as shown in Fig. 31.1 (a, b).

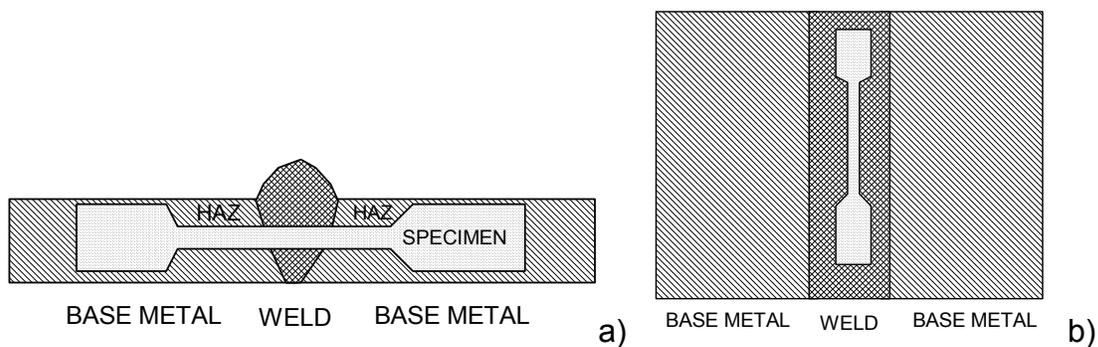


Fig. 31.1 Schematic of tensile specimens from a) transverse section of weld joints and b) all weld specimen

Tensile test results must be supported by respective engineering stress and strain diagram indicating modulus of elasticity, elongation at fracture, yield and ultimate strength (Fig. 31.2). Tests results must includes information on following point about test conditions

- Type of sample (transverse weld, all weld specimen)
- Strain rate (mm/min)
- Temperature or any other environment in which test was conducted if any
- Topography, morphology, texture of the fracture surface indicating the mode of fracture and respective stress state

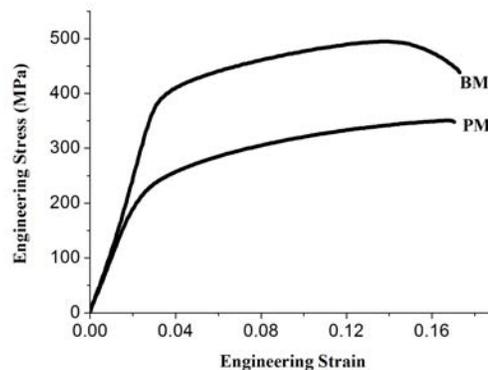


Fig. 31.2 Typical stress strain diagram for AA 7039 in as received (BM) and friction stir processed (PM) condition

31.2.2 Bend test

Bend test is one of the most important and commonly used destructive tests to determine the ductility and soundness (for the presence porosity, inclusion, penetration and other macro-size internal weld discontinuities) of the weld joint produced using under one set of welding conditions. Bending of the weld joint can be done from face or root side depending upon the purpose i.e. whether face or root side of the weld is to be assessed. The root side bending shows the lack of penetration and fusion if any at the root. Further, bending can be performed using simple compressive/bending load and die of standard size for free and guided bending respectively (Fig. 31.3, 31.4). Moreover, free bending can be face or root bending while guided bending is performed by placing the weld joint

over the die as needs for bending is better and controlled condition as shown in Fig. 31.4.

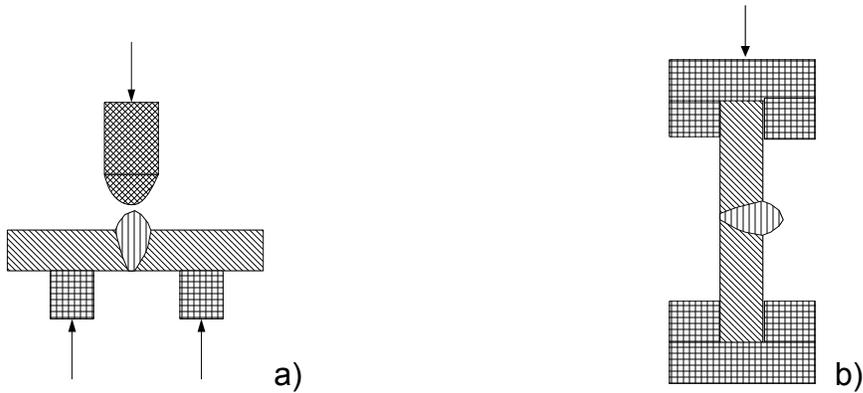


Fig. 31.3 Schematics of free bend tests

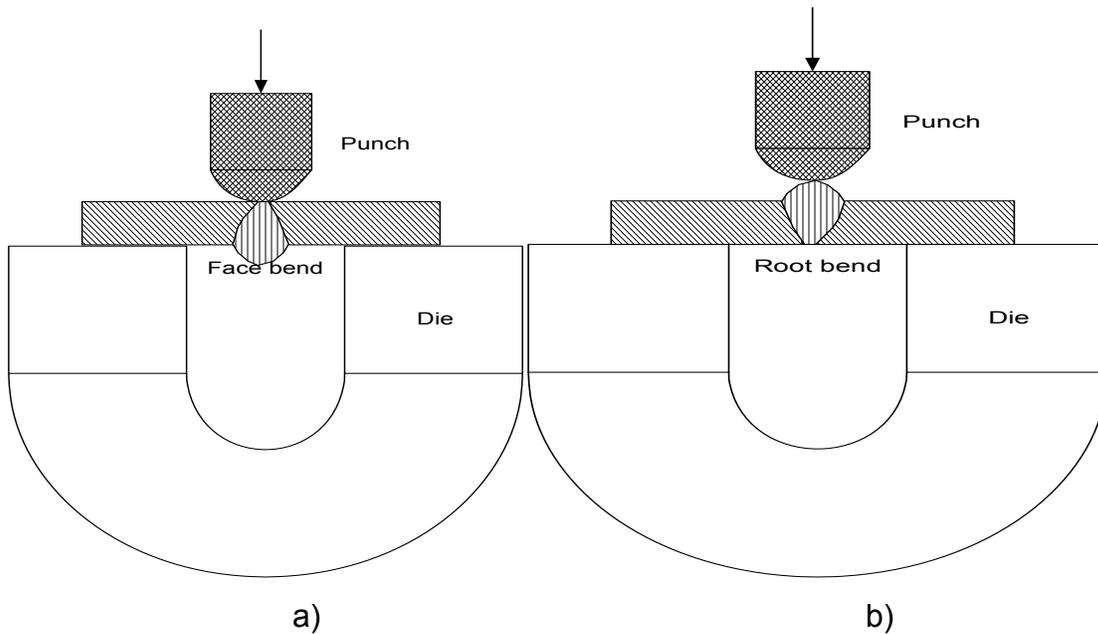


Fig. 31.4 Schematics of guided bend tests a) face bend and b) root bend.

For bend test, the load increased until cracks start to appear on face or root of the weld for face and root bend test respectively and angle of bend at this stage is used as a measured of ductility of weld joints. Higher is bend angle (needed for crack initiation) greater is ductility of the weld. Fracture surface of the joint from the face/root side due to bending reveals the presence of internal weld discontinuities if any.

31.2.3 Hardness test

Hardness is defined as resistance to indentation and is commonly used as a measure of resistance to abrasion or scratching. For the formation of a scratch or causing abrasion, a relative movement is required between two bodies and out of two one body must penetrate/indent into other body. Indentation is the penetration of a pointed object (harder) into other object (softer) under the external load. Resistance to the penetration of pointed object (indenter) into the softer one depends on the hardness of the sample on which load is applied through the indenter.

All methods of hardness testing are based on the principle of applying the standard load through the indenter (a pointed object) and measuring the penetration in terms of diameter/diagonal/depth of indentation (Fig. 31.5). High penetration of an indenter at a given standard load suggests low hardness. Various methods of hardness testing can be compared on the basis of following three criteria 1) type of indenter, 2) magnitude of load and 3) measurement of indentation.

Parameter	Brinell	Rockwell	Knoop	Vickers
Load	500-2000 kg	Minor: 10 kg Major: 60 to 200 kg as dictated by scale to be used (A-C)	10 to 3000 g	
Indenter	Ball	Ball or cone	Cone	Pyramid
Measurement	Diameter	Depth	Diagonal	Diagonal

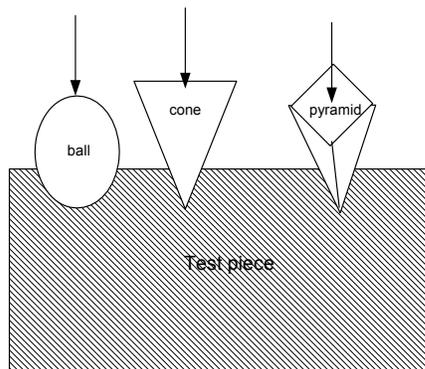


Fig. 31.5 Schematic diagram showing indentation using different indenters corresponding to different hardness test methods

Penetration due to applied normal load is affected by unevenness on the surface and presence of hard surface films such as oxides, lubricants, dust and dirt etc. if any. Therefore, surface should be cleaned and polished before hardness test. In case of Brinell hardness test, full load is applied directly for causing indentation for measuring hardness while in case of Rockwell hardness test, minor load (10 kN) is applied first before applying major load. Minor load is applied to ensure the firm metallic contact between the indenter and sample surface by breaking surface films and impurities if any present on the surface. Minor load does not cause indentation. Indentation is caused by major load only. Therefore, cleaning and polishing of the surface films becomes mandatory for accuracy in hardness test results in case of Brinell test method as major load is applied directly.

Steel ball of different diameters (D) is used as an indenter in Brinell hardness test. Diameter of indentation (d) is measured to calculate the projected area and determine the hardness. Brinell hardness test results are expressed in terms of pressure generated due to load (P). It is calculated by the ratio of load applied and projected contact area. Load in the range of 500 to 3000 kg can be applied depending upon the type of material to be tested. Higher load is applied for hardness testing of hard materials as compared to soft materials.

$$\text{BHN} = \frac{2P}{\pi D [D - (D^2 - d^2)^{1/2}]}$$

In case of Rockwell hardness test first minor load of 10 kg is applied and then major load of 50-150kg is applied on the surface of the work-piece through the indenter and the same is decided by scale (A, B, C and D) to be used as per type of material to be tested. Minor load is not changed. Out of mainly scales, B and C scales are commonly used. Different indenter and major load are required for each scale. Steel ball and diamond cone are two types of indenters used in Rockwell testing. B scale uses hardened steel ball and major load of 90kg whereas C scale uses diamond cone and major load of 140kg accordingly hardness is written in terms of HRB and HRC respectively.

Vickers hardness test uses square pyramid shape indenter of diamond and load ranging from 1 to 120 kg. Average length (L) of two diagonals of square indentation is used as a measure of hardness. Longer is average diagonal length lower is hardness. Vickers hardness number (VHN) or diamond pyramid hardness (DPH) is the ratio of load (P) and apparent area of indentation given by

the relation:
$$DPH = \frac{1.854P}{L^2}$$

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