Inspection of weld (NDT) - Visual inspection

Objectives: At the end of this lesson you shall be able to
- **explain the necessity of inspection and testing of weld**
- **describe the different stages of visual inspection**
- **explain the check points of visual inspection**
- **state types of testing of welds.**

Necessity of inspection: The purpose of inspection is to locate and determine the type of weld fault, strength and quality of joint and quality of workmanship.

Types of tests

– Non-destructive test (NDT)

– Destructive test

– Semi destructive test

Determining the quality of the weld without destroying the weld is called a non-destructive test (NDT). The job can be used after the test. The test to be carried out on welded specimens by cutting the job and destroying it is called destructive test. The job cannot be used after the test.

Sometimes the quality of a welded joint is tested by grinding, drilling, etching, filing etc. for finding machinability, microstructure etc. These tests are called semi-destructive tests. The tested job can be used after the test by rewelding the small area damaged during the test.

Visual inspection (non-destructive test): Visual inspection is observing the weld externally using simple hand tools and gauges to know whether there is any external weld defects. This is one of the important inspection methods without much expense. This method of inspection needs a magnifying glass, a steel rule, try square and weld gauges. Visual inspection is made in three stages namely:

– before welding

– during welding

– after welding

Visual inspection before welding

(The operator must be familiar with the type of work, electrode and welding machine)

The following factors are to be ensured.

The material to be welded is of weldable quality.

The edges have been properly prepared for welding as per thickness of the plate.

Proper cleaning of the base metal.

Setting of proper root gap.

Proper procedure to be followed to control distortion.

Proper selection of blow pipe nozzle and filler rod, flux and flame.

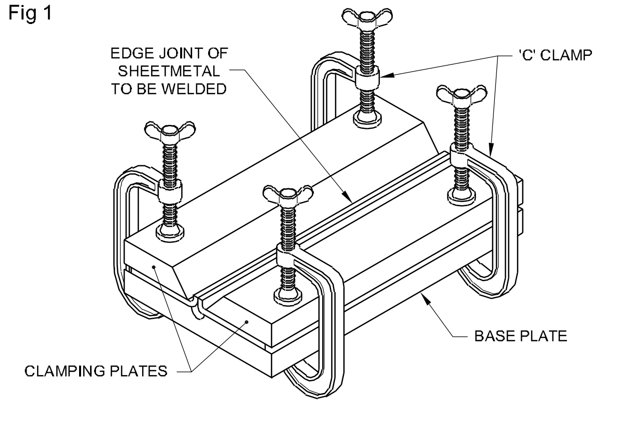
Polarity of the electrodes in the case of DC welding current.

Whether the cable connections are tight.

Current setting according to the size of the electrode and position of welding.

Whether any jigs and fixtures are necessary to ensure proper alignment. (Fig 1)

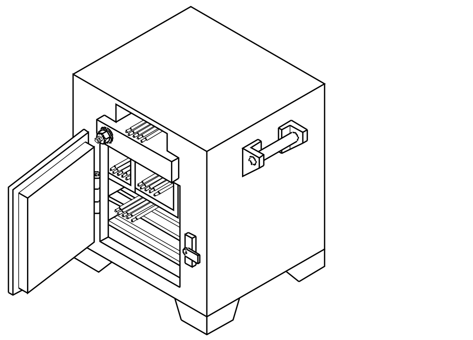
Fig 1



CLAMPING PIECES BETWEEN HEAVY BLOCKS WILL KEEP THEM STRAIGHT.

Proper facilities should exist for storing and drying of the electrodes. (Fig 2)

Fig 2



ELECTRODE DRYING OVAN

Visual inspection during welding

The following points are to be checked.

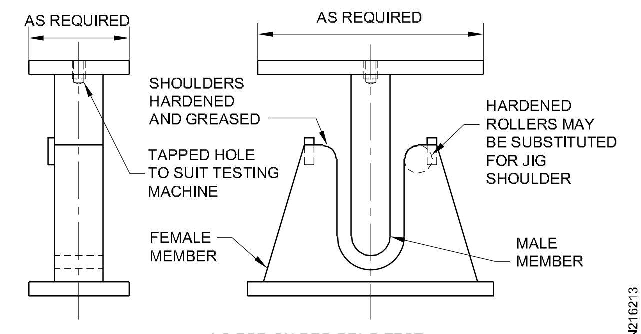
Studying the sequence of weld deposit.

Examining whether each weld is cleaned adequately before making the next run in multi-run welding.

The following factors are to be ensured.

Guided bend test: A guided bend test is one in which the specimen as in Fig.3.

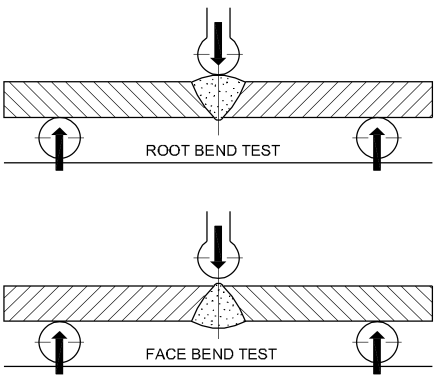
Fig 3



JIG FOR GUIDED BEND TEST

There are two types of specimens prepared for this - one for face bend and the other for root bend. (Fig.4) This test measures the ductility of the weld metal in a butt joint in a plate. This test shows most weld faults quite accurately and it is very fast. A sample specimen can be tested on destruction to determine (a) the physical condition of the weld and thus check on the weld procedure and (b) the welder's capability.

Fig 4

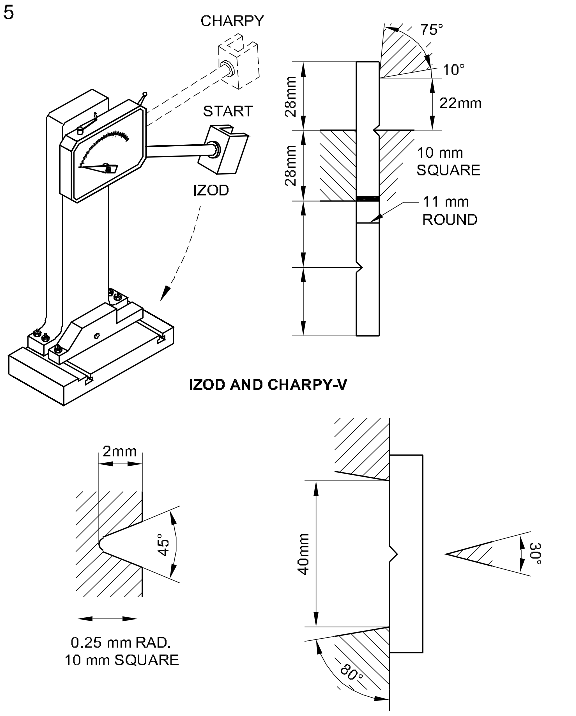


Impact test: Impact means application of a sudden force on an object. In an impact test of a weld, a test specimen (Fig.4) is prepared from a test plate. This is further machined to have a V notch as in Fig.5. The test specimen with 10 mm square cross-section is used for charpy V impact test and one with 11 mm diameter circular cross-section is used for the izod impact test. Fig.6 shows an impact testing machine.

The impact test is used to determine the impact value of welds and base metals in welded products to be used at low temperatures up to - 40^0 C which are subjected to severe dynamic loading.

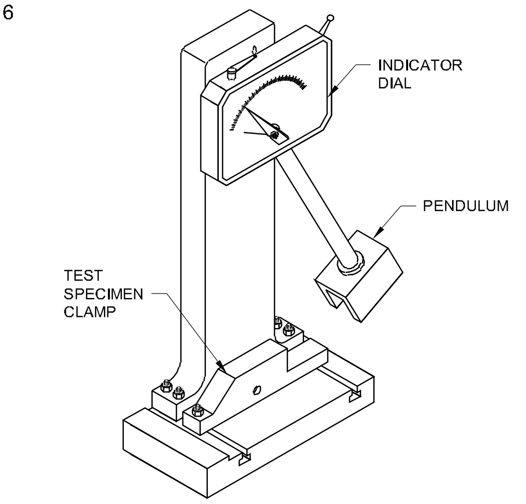
Fatigue test: When a welded joint is subjected to push and pull forces alternatively for a long period, it may fail due to the fatigue of the molecules. In this case the forces applied will rise to a maximum tension, decrease to zero, rise to a maximum compression and decrease again to zero. This cycle will be repeated which creates fatigue in the joint which will fail at much less loads than its maximum tension and compression strength.

Fig 5



IZOD AND CHARPY - V MACHINE AND SPECIMENS IMPACT TEST

Fig 6



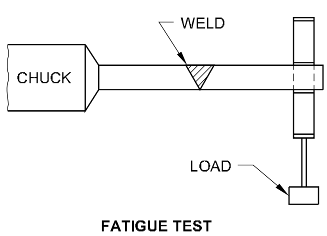
A CHARPY IMPACT TESTING MACHINE

IN THIS TESTER THE PENDULUM IS LIFTEDAND DROPED AGAINST THE TEST SPECIMEN WHICH IS HELD IN THE CLAMP. THE IMPACT FORCE IS REGISTERED BY THE DIAL INDICATOR.

The resistance to fatigue of a welded joint is tested by fixing the welded specimen in a chuck and rotated at a particular speed with a load hung at the other end as shown in Fig.7. Fatigue tests are extremely useful while testing welded shafts, cranks and other rotating parts which are subjected to varying alternating loads.

Fig 7

ILLUSTRATING PRINCIPLE OF WOHLER TEST



FATIGUE TEST

Measuring gauges

Objectives: At the end of this lesson you shall be able to
- **describe the surface defects on weld**
- **explain the measuring gauges**
- **states the types of gauges.**

Inspection after welding: Surface defects in and around the welds, such as cracks, (longitudinal and transverse) (Fig.1), undercut (Fig.2), overlap (Fig.3), excessive convexity of contour, the weld surface smoothness of the run and penetration, control of distortion, unfilled crater are to be inspected.

Fig 1

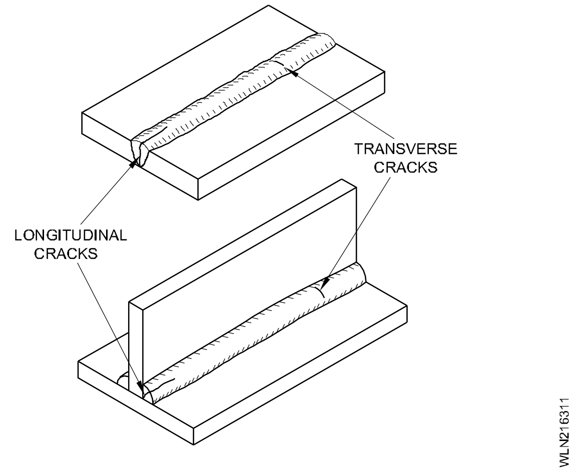


Fig 2

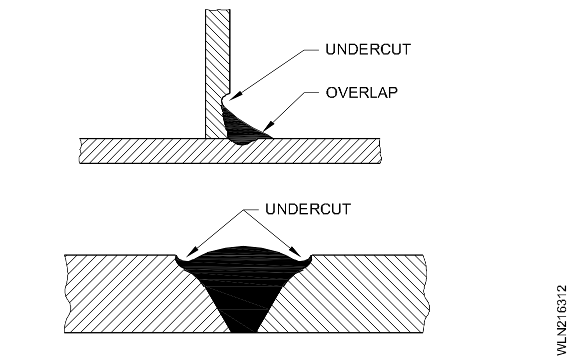
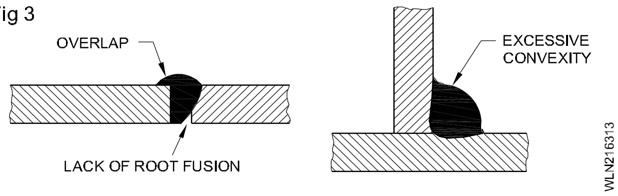


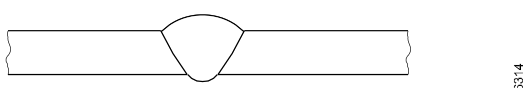
Fig 3



Freedom from surface cavities and slag inclusions. (Fig 4). Deposition of runs, single or multiple.

Penetration bead in butt weld.

Fig 4



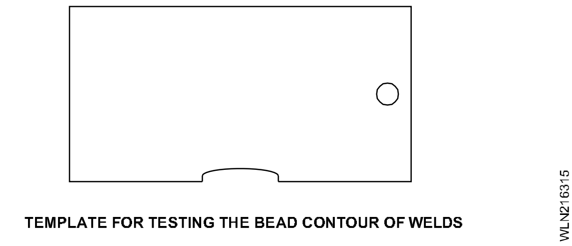
FREE FROM SURFACE CAVITIES AND SLAG INCLUSIONS

Quality of the weld metal.

Measuring gauges used for inspection

A template may be used to check the contour. (Fig.5)

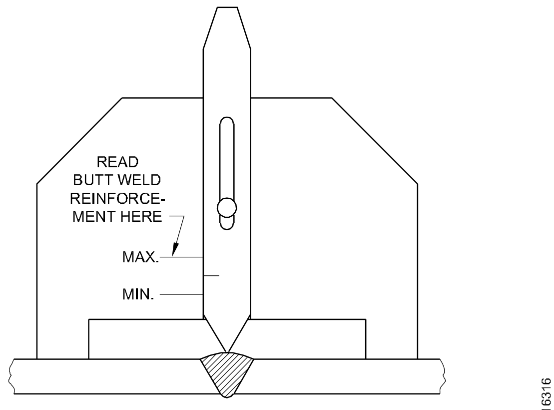
Fig 5



TEMPLATE FOR TESTING THE BEAD CONTOUR OF WELDS

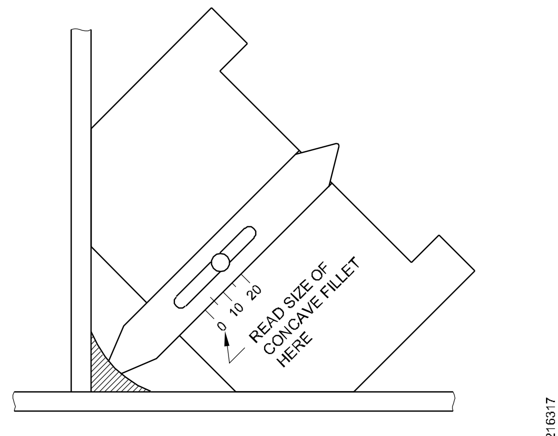
Use gauges for measuring both convex and concave in fillet weld and to check contour of weld. (Figs 6 to 12)

Fig 6

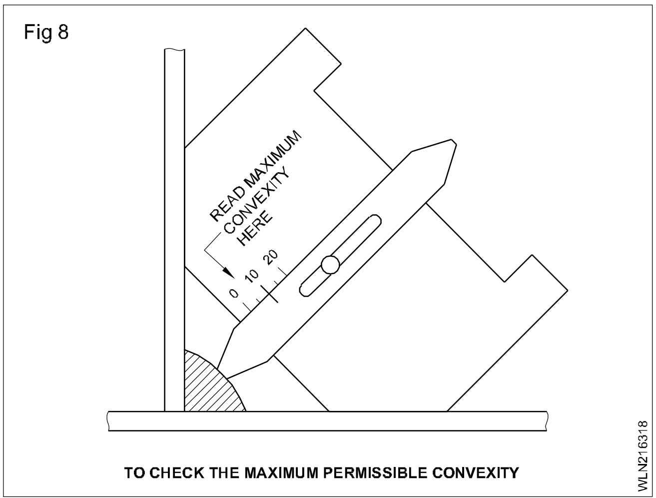


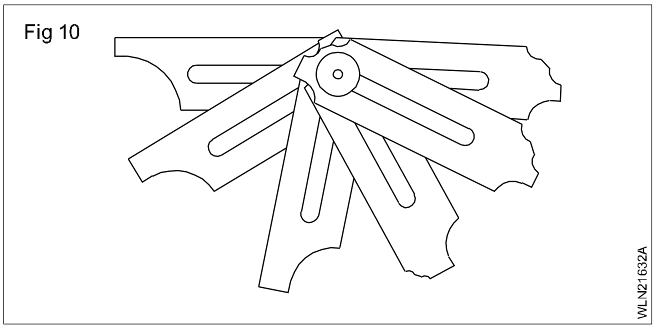
CHECKING BUTT WELD FOR MAXIMUM AND MINIMUM CONVEXITY

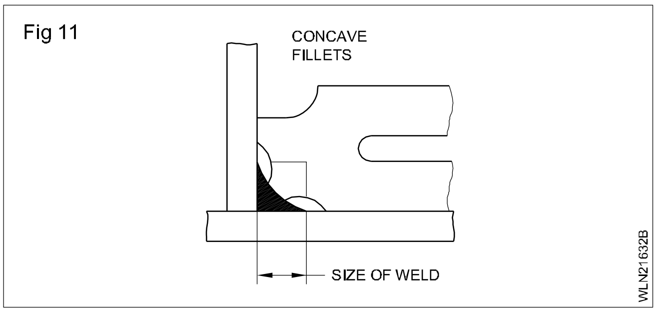
Fig 7

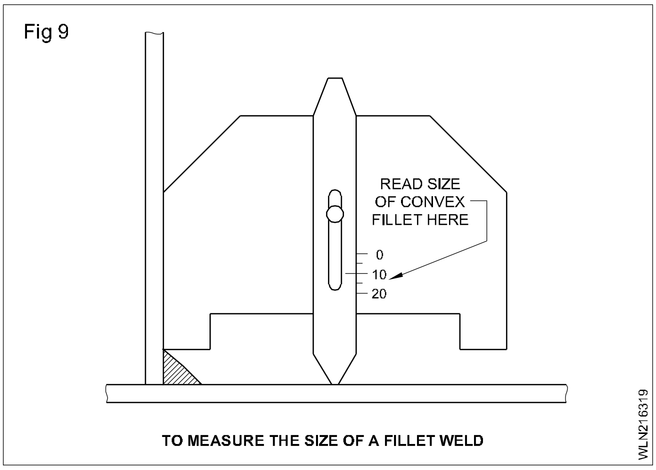


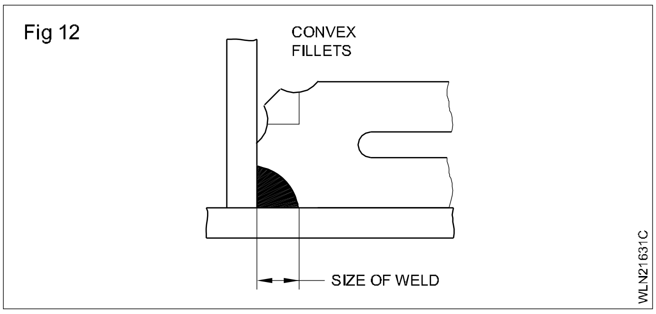
TO DETERMINE THE SIZE OF A CONCAVE FILLET











Methods of non-destructive tests

Objectives: At the end of this lesson you shall be able to
- **explain the non-destructive testing methods**
- **explain the uses of the common non-destructive methods**
- **explain the uses of special non-destructive testing.**

Non-destructive testing methods are classified as common testing and special testing methods.

Common non-destructive testing

– Visual inspection

– Leak or pressure test

– Stethoscopic test (Sound)

Special non-destructive tests

– Magnetic particle test

– Liquid penetrant test

– Radiography (X-ray) test

– Gamma ray test

– Ultrasonic test

Visual inspection: Visual inspection is the simplest, fastest, economical and most commonly used test for detecting defects on the surface of the welded job. The weld surface and joint are examined visually with naked eyes preferably with the help of a magnifying lens. Visual examination can help in detecting the following defects on the surface of the weld.

– Porosity

– Surface defects like surface cracks, external slag inclusions, overlap, spatters, unfilled crater, misalignment, distortion etc.

– Undercut

– Improper profile and dimensional accuracy

– Poor weld appearance

– Incomplete penetration.

Leak or pressure test: This test is used to test welded pressure vessels, tanks and pipelines to determine if leaks are present. The welded vessel, after closing all its outlets, is subjected to internal pressure using water, air or kerosene. The internal pressure depends upon the working pressure which the welded joint has to withstand. The internal pressure may be raised to two times the working pressure of the vessel. The weld may be tested as follows.

1 The pressure on the gauge may be noted immediately after applying the internal pressure and again after, say, 12 to 24 hours. Any drop in pressure reading indicates a leak.

2 After generating air pressure in the vessel, soap solution may be applied on the weld seam and carefully inspected for bubbles which would indicate leak.

Stethoscopic (sound) test: The principle of this test is that defect-free weld metal gives a good ringing sound when struck with a hammer whereas a weld metal containing defects gives a flat sound.

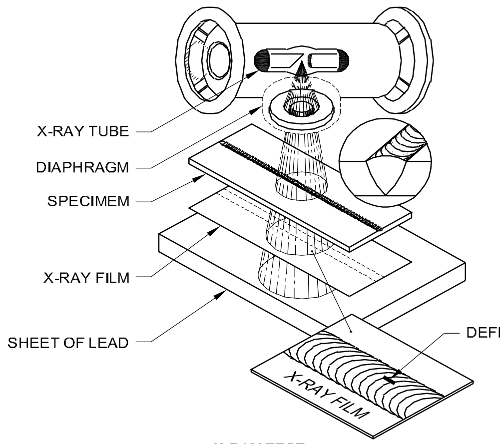
An ordinary physician's stethoscope and a hammer may be used to magnify and identify the sound.

Structural welds and welds in pressure vessels have been successfully tested using this method.

Radiographic test: This test is also called X-ray or gamma ray test.

X-ray test: In this test internal photographs of the welds are taken. The test specimen is placed in between the X-ray unit and film. (Fig 1) Then the X-ray is passed. If there is any hidden defect, that will be seen in the film after developing it. Defects appear in the same manner as bone fractures of human beings appear in X-ray films. Below the X-ray film a lead sheet is kept to arrest the flow of X-ray further from the X-ray testing machine.

Fig 1



X-RAY TEST

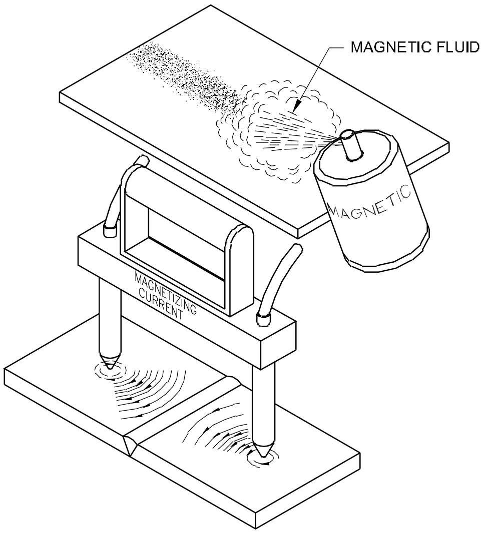
Gamma ray test: The short invisible rays given off by radium and radium compounds like cobalt 60 etc. are known as gamma rays. These rays penertrate greater thickness of steel than x-rays and the chief advantage of this process is portability. This test can be done at places where electricity is not available. These tests are used on high quality jobs like boilers and high pressure vessels and penstock pipes and nuclear vessels.

Magnetic particle test: This test is used to detect surface defects as well as sub-surface (up to 6 mm depth) defects in ferrous materials.

A liquid containing iron powder is first sprayed over the joint to be tested. When this test piece is magnetised, the iron particles will gather at the edges of the defect (crack or flaw) and can be seen as dark hair line marks with naked eyes. (Figs 2 & 3)

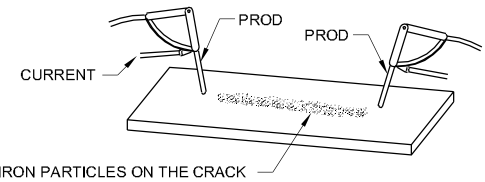
Liquid penetrant test; This test is based on the principle that coloured liquid dyes and fluorescent liquid penetrate into the cracks and are used to check for surface defects in metals, plastics, ceramics and glass. A solution of the

Fig 2



MAGNETIC PARTICLE TEST

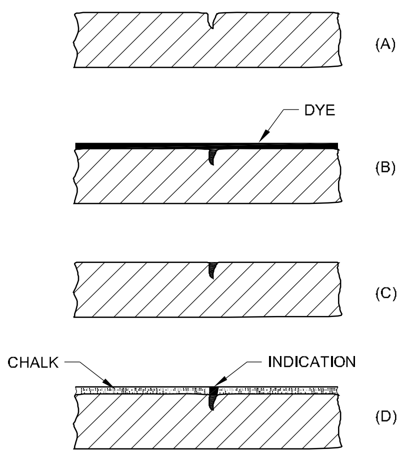
Fig 3



coloured dye is sprayed on the clean welded joint and allowed to soak. Then the dye is washed off using a cleaner, and the surface dried with soft cloth.

A liquid developer (white in colour) is then sprayed on the weld. The coloured dye comes out in the shape of surface defects into the white developer coating. The defect can be seen in normal light with naked eyes. (Fig 4)

Fig 4

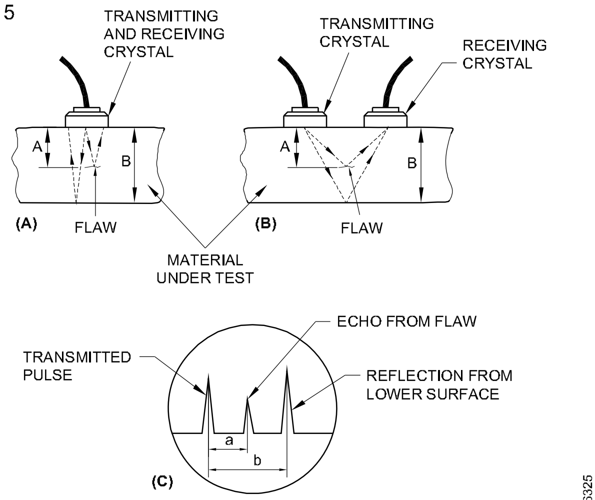


LIQUID PENETRANT TEST

Ultrasonic test: Sound waves of high frequency are used in this test. This test is used to find out the discontinuities in the weldment. The sound waves can penetrate from a very small thickness of plate to 6 to 10 metres of steel.

A sound wave producing transmitter is placed on the job. The echo of the sound waves is directly shown on the calibrated screen attached with the ultrasonic testing unit. (Fig 5)

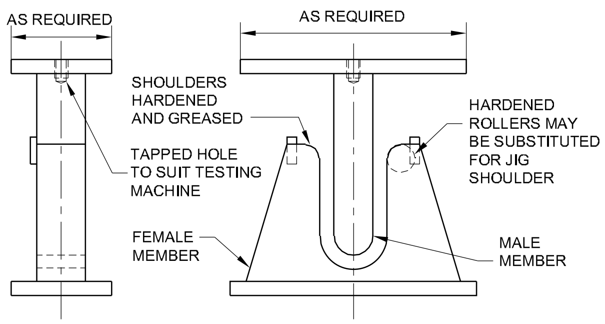
Fig 5



PRINCIPLE OF ULTRASONIC INSPECTION

Guided bend test: A guided bend test is one in which the specimen as in Fig. 6.

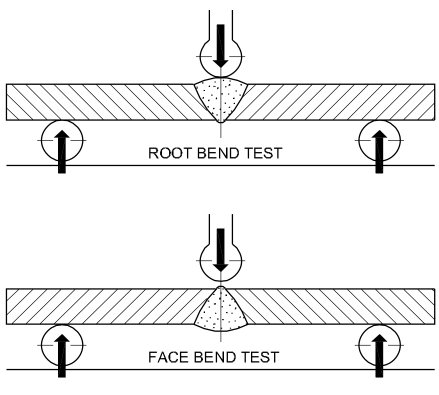
Fig 6



JIG FOR GUIDED BEND TEST

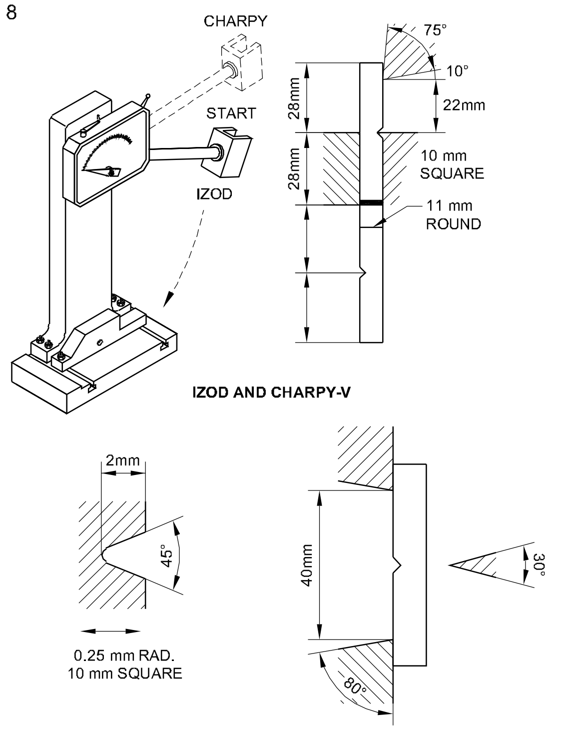
There are two types of specimens prepared for this - one for face bend and the other for root bend. (Fig. 7) This test measures the ductility of the weld metal in a butt joint in a plate. This test shows most weld faults quite accurately and it is very fast. A sample specimen can be tested on destruction to determine (a) the physical condition of the weld and thus check on the weld procedure and (b) the welder's capability.

Fig 7



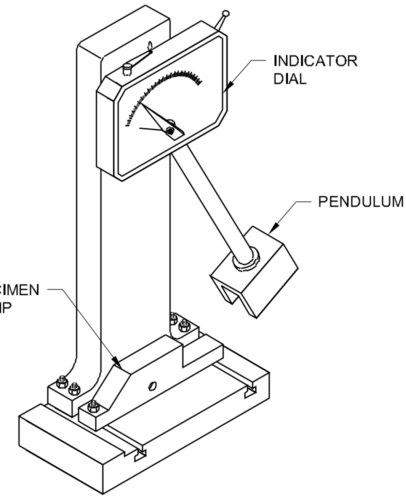
Impact test: Impact means application of a sudden force on an object. In an impact test of a weld, a test specimen (Fig. 8) is prepared from a test plate. This is further machined to have a V notch as in Fig.8. The test specimen with 10 mm square cross-section is used for charpy V impact test and one with 11 mm diameter circular cross-section is used for the izod impact test. Fig.9 shows an impact testing machine.

Fig 8



IZOD AND CHARPY - V MACHINE AND SPECIMENS IMPACT TEST

Fig 9



A CHARPY IMPACT TESTING MACHINE

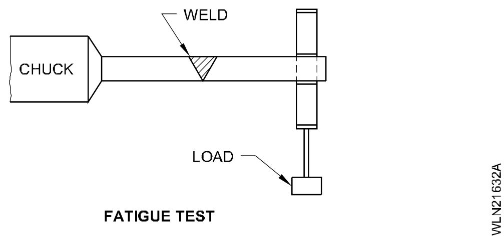
IN THIS TESTER THE PENDULUM IS LIFTEDAND DROPED AGAINST THE TEST SPECIMEN WHICH IS HELD IN THE CLAMP. THE IMPACT FORCE IS REGISTERED BY THE DIAL INDICATOR.

The impact test is used to determine the impact value of welds and base metals in welded products to be used at low temperatures up to - 40^0 C which are subjected to severe dynamic loading.

Fatigue test: When a welded joint is subjected to push and pull forces alternatively for a long period, it may fail due to the fatigue of the molecules. In this case the forces applied will rise to a maximum tension, decrease to zero, rise to a maximum compression and decrease again to zero. This cycle will be repeated which creates fatigue in the joint which will fail at much less loads than its maximum tension and compression strength.

The resistance to fatigue of a welded joint is tested by fixing the welded specimen in a chuck and rotated at a particular speed with a load hung at the other end as shown in Fig.10 Fatigue tests are extremely useful while testing welded shafts, cranks and other rotating parts which are subjected to varying alternating loads.

Fig 10 ILLUSTRATING PRINCIPLE OF WOHLER TEST



FATIGUE TEST

Destructive tests

Objectives: At the end of this lesson you shall be able to
- **explain the necessity for destructive tests**
- **explain the different methods of destructive test of weldments**
- **explain the advantages and limitations of workshop and laboratory tests**
- **identify the specimen for destructive tests.**

Introduction: Welded joints are tested without damaging or destroying the welded structure under non-destructive testing methods which were explained earlier. Now to know the property of material used for welding and to know the strength of a weld joint and also to judge the skill of the welder, a destructive test is to be performed on a welded specimen which was destroyed during the testing. There are two main methods of destructive testing. They are:

- workshop tests
- laboratory tests

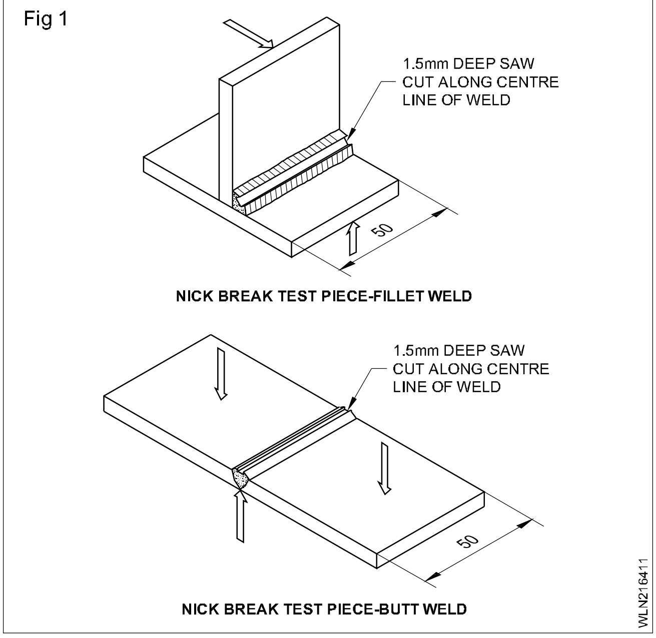
Workshop tests

These are the tests that can be performed in the workshop.

- Nick break test
- Free bend test in a vice
- Fillet fracture test (by using a bending bar)

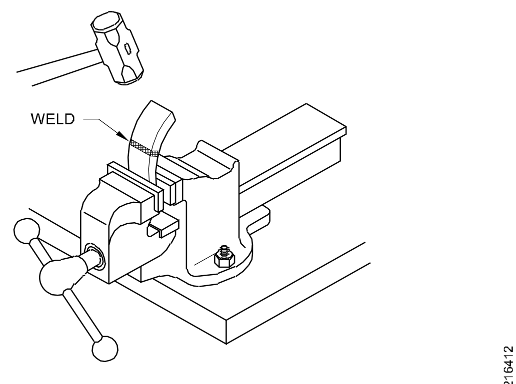
Nick break test: In a nick break test a saw cut of about 1.5mm to 2mm depth is made along the centre line of the weld, and a hammer blow is given on the reverse of the joint as shown in the figure. (Fig 1). The joint will break along the saw cut and by observing the fractured surface, various defects like slag inclusions, lack of fusion, lack of penetration, etc. can be identified.

Fig 1



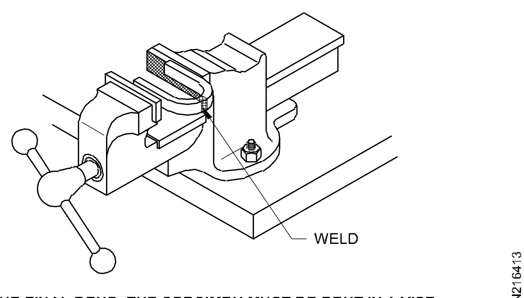
Free bend test: The welded joints are fixed on a vice and bent by applying forces by hammer/bending bar to determine the defect in the weld done by a trainee in a workshop. (Figs 2&3) The workshop tests are usually used to break open the weld in a workshop using a vice and hammer for visual inspection.

Fig 2



THIS IS ONE WAY THE INITIAL BEND CAN BE MADE

Fig 3



FOR THE FINAL BEND, THE SPECIMEN MUST BE BENT IN A VISE

Advantages and limitations: The time taken to perform the test is less. Cost of testing is less. This test is useful for testing the welders in the beginning when the weld contains many defects. Does not give the actual strength of the joint. Cannot be used for testing the quality of weld consumables. (electrodes and filler rods)

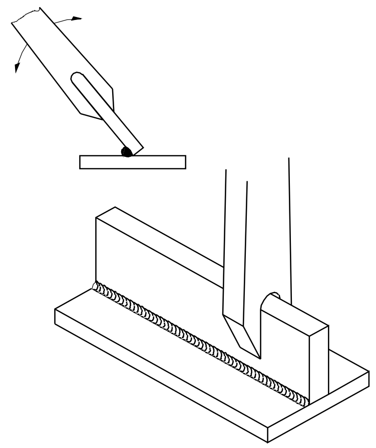
Examination of fractured weld: The fractured weld may exhibit and show the following internal defects. (Figs 4, 5,6, and 7)

- Lack of fusion
- Incomplete penetration
- Slag inclusions
- Blow-holes or porous weld

Laboratory tests

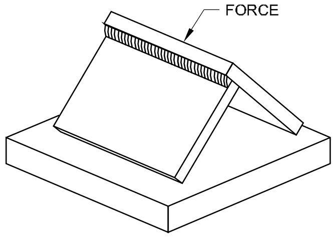
The laboratory tests conducted on welds are the:

Fig 4



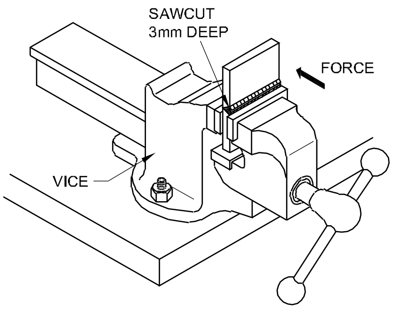
FILLET FRACTURE TEST USING BENDING BAR

Fig 5



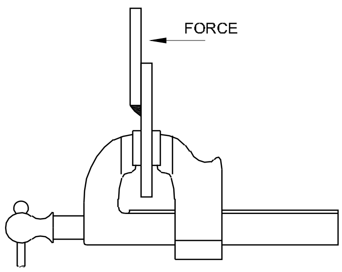
FILLET FRACTURE TEST USING HAMMER

Fig 6



FRACTURE TEST ON BUTT JOINT

Fig 7



FRACTURE TEST ON LAP FILLET

– tensile test
– guided bend test
– impact test
– fatigue test.

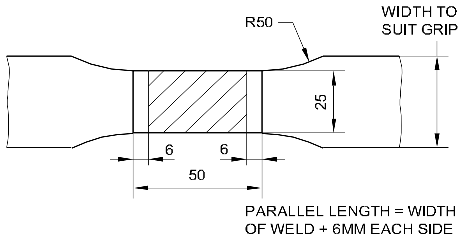
Tensile test: A tensile test is conducted to know the tensile strength and ductility (i.e. elongation) of a weld.

Two types of test specimens are prepared for the tensile test.

They are

– transverse tensile test specimen (Fig 8)

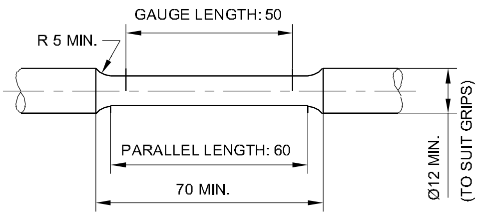
Fig 8



DIMENSIONS OF TRANSVERSE TENSILE TEST SPECIMEN

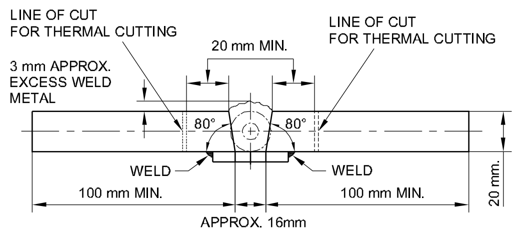
– all-weld metal tensile specimen. (Figs 9 and 10)

Fig 9



ALL-WELD METAL TENSION SPECIMEN

Fig 10



LOCATION OF ALL-WELD METAL TENSION SPECIMEN (END VIEW)

The tensile test gives the values of the tensile strength of the weld and the percentage of elongation of the weld. This reveals the suitability of a joint welded with certain electrodes and base metals for a particular service condition.

Economy in welding & simple estimation

Objectives: At the end of this lesson you shall be able to
- **describe the method of cost estimation**
- **explain about economy in welding**
- **explain the principle, application, advantages and limitations of electron beam, electro slag, friction and laser beam welding**
- **describe the parts of the above advanced welding equipment.**

The following factors are to be considered for cost estimation.

Material cost: Material cost involves the cost of all basic materials such as steel sheets, plates, rolled sections, forgings, angle irons, forgings, casting etc. as may be used.

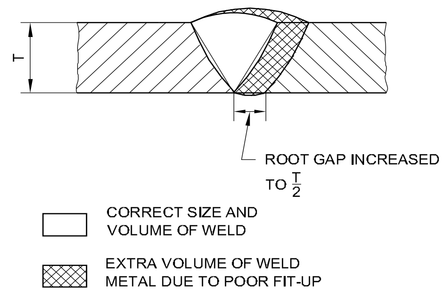
Fabrication cost: Fabrication cost involves cost of (1) preparation (2) welding and (3) finishing.

Preparation cost: Preparation cost involves cost of material handling, cutting, machining or shearing plates or sections, preparing the edges for welding, forming, fitting up, positioning, labour for these operations etc.

Welders should ensure that the plates and sections are prepared for welding, either by machining or by flame cutting in accordance with the recommendations of the design office.

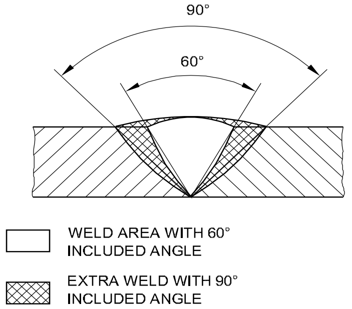
The effects of inaccurate edge preparation and poor fit up resulting in extra welding and the consequent additional welding costs are illustrated in Figs 1 and 2.

Fig 1



EFFECTS OF POOR FIT-UP IN A BUTT WELD: EXTRA WELDING AND HIGHER COST

Fig 2



BUTT WELD MADE WITH BEVELLED EDGE: 60° INCLUDED ANGLE (CORRECT) AND 90° INCLUDED ANGLE (INCORRECT)

Welding cost: The welding cost involves the cost of electrodes, power consumed, welding labour etc.

In determining the direct welding cost, the following factors are taken into consideration.

- Cost of electrodes - this being dependent on the type and size of electrode and edge preparation employed.
- Power consumed

$$\text{Power cost} = \frac{V \times A}{1000} \times \frac{T}{60} \times \frac{1}{E} \times \text{rate per unit}$$

where V = Voltage, A = Current in amperes

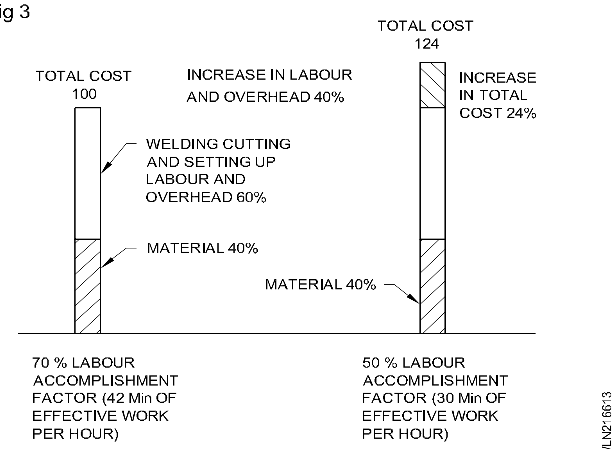
T = Welding time in minutes

E = Efficiency of the machine.

E is assumed to be 0.6 in the case of a welding transformer and 0.25 in the case of a welding generator.

- Speed of welding
- Welding labour cost (Fig 3)
- Position of welding

Fig 3

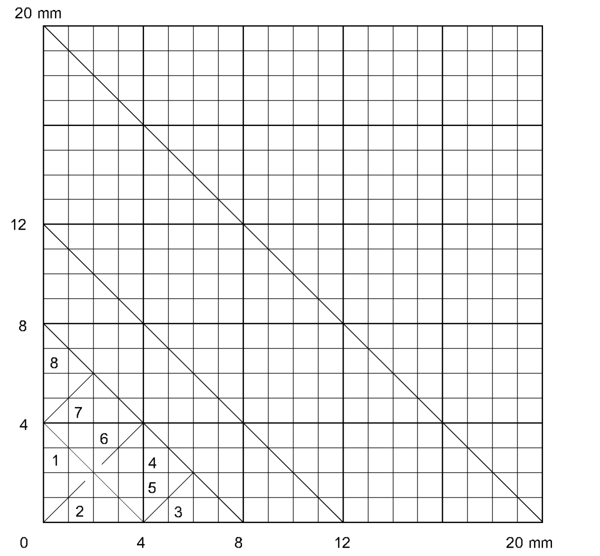


Finishing cost: Finishing cost involves cost of all post welding work, such as machining, grinding, sand-blasting, pickling, heat treatment, painting etc. and the labour involved in carrying out these operations.

Overhead cost: Overhead costs involve all other costs, such as office and supervisory expenses, lighting, depreciation on capital, etc. which are not to be directly charged to a job. There exists an elaborate and accurate system of computation and allocation of overhead expenses to the various stages of manufacturing process.

Economics of welding: Over-welding, that is excessive build up in the case of butt weld and fillet welds larger than those specified, should always be avoided. (See size comparison in Fig 4)

Fig 4



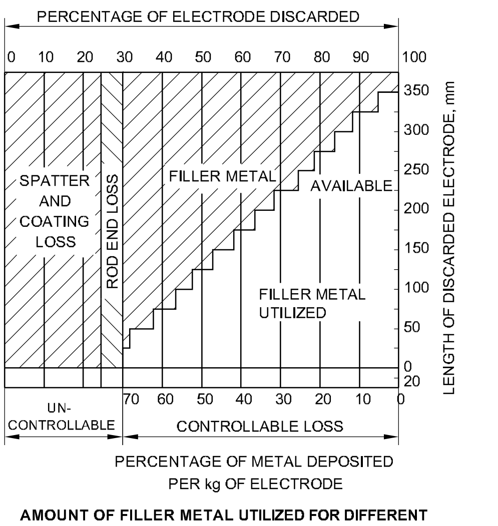
COMPARATIVE SIZE OF 90° FILLETS

Ensure that the largest size of electrode compatible with the plate thickness is used. Use of smaller electrode will increase labour hours and excessive distortion.

Use proper welding current. Excessive current will lead to excessive spatter loss and unsatisfactory weld.

Avoid excessive stub end loss; ensure that most of the usable portion of the electrode is used. The stub end should never be more than 50mm. (Fig 5)

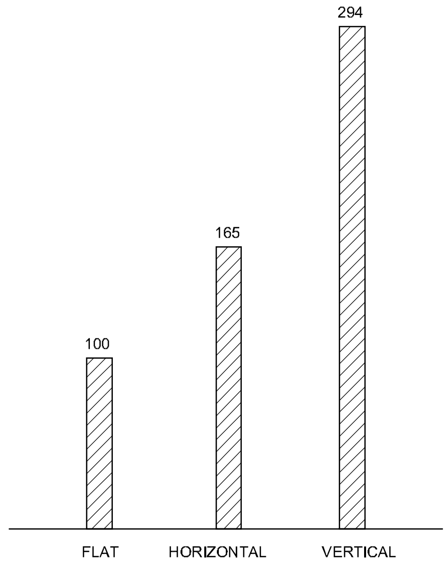
Fig 5



AMOUNT OF FILLER METAL UTILIZED FOR DIFFERENT DISCARDED LENGTHS OF ELECTRODES

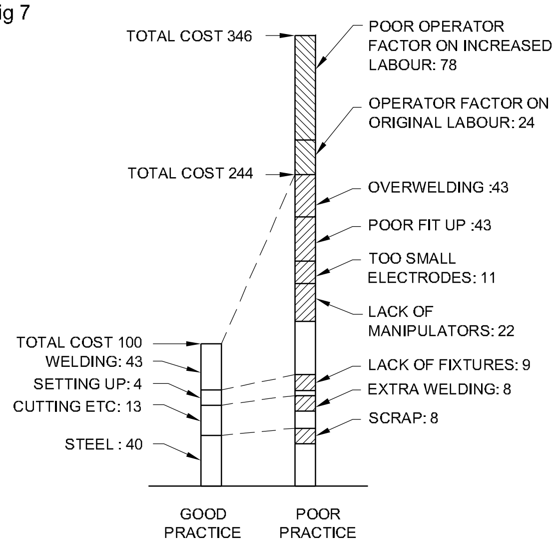
The most convenient position of welding is in the down hand (flat) position. Whenever possible welding should be carried out in the flat position. A graphic form of the relative cost and speed of welding is shown in Fig 6 & 7.

Fig 6



RELATIVE COSTS AND SPEEDS FOR MAKING 10mm FILLET WELDS IN DIFFERENT POSITION

Fig 7



CUMULATIVE EFFECT OF POOR PRACTICES ON COST