Taoufik Tebbai

Welding inspection

Metropolia Ammattikorkeakoulu

Tutkinto: insiöörni (AMK)

Koulutusohjelma: Kone- ja tuotantotekniikka

insinöörityö: Hitsaustarkastus

Tekijä Otsikko Sivumäärä	Taoufik Tebbai Hitsaustarkastus 69 sivua
Tutkinto	Insinööri (AMK)
Koulutusohjelma	Kone- ja tuotantotekniikka
Suuntautumisvaihtoehto	Koneensuunnittelu
Ohjaaja(t)	Joel Kontturi

Tämän insinöörityön tavoitteena on selvittää, miten metalli- ja hitsausalalla hyvin koulutettujen, aktiivisten ja rehellisten hitsaustarkastajien työ vaikuttaa yrityksen tuotannon laatuun ja asiakastyytyväisyyteen. Työssä tarkastellaan hitsaustarkastajan työn vaatimuksia ja perehdytään erityisesti NDT-tarkastuksiin.

Hitsattujen rakenteiden valmistajalla tulee olla käytettävissään riittävä määrä hitsaustarkastajia suunnittelemaan, suorittamaan, neuvomaan ja valvomaan hitsauksen tarkastusta, testausta ja arvioimista eriteltyjen vaatimusten mukaisesti. Valmistajan tulee laatia ja ylläpitää myös työohjeita asiaankuuluvien dokumenttien laatimiseksi ja valvomiseksi. Tällaisia ovat esimerkki hitsausohjeet, hitsausohjeiden hyväksymispöytäkirja sekä hitsausoperaattoreiden pätevyystodistukset.

Hitsaustarkastajan pätevyyteen vaaditaan, että pitää hallita NDT-tarkastus, hitsausprosessi, työ- ja työympäristöturvallisuus sekä olla fyysisesti soveltuva. Pääsyvaatimuksena hitsaustarkastajan koulutukseen vaaditaan kone- ja metallitekniikan teknikon, insinöörin tai diplomi-insinöörin tutkinto ja vähintään 5 vuoden työkokemus.

Ainetta rikkomattomien NDT-menetelmien pätevöintikäytännöllä pyritään varmistamaan kulloinkin käytettävään tarkastussovellukseen riittävä suorituskyky. Pätevöinnissä noudatetaan järjestelmällistä ja tarkasti dokumentoivaa lähestymistapaa, mikä asettaa uusia vaatimuksia tarkastuksia koskevien asiakirjojen laatimiselle. Tässä työssä annetaan NDT-menetelmistä ohjeet, jotka liittyvät radiografian, ultraäänen ja tunkeumanesteen käyttöön.

Työn lopputuloksena todetaan, että hyvin luotettava koulutettu tarkastaja, jatkuva tarkkailu ja dokumentoitu toiminta vaikuttavat hitsauksen laatuun ja taloudellisuuteen sekä asiakkaan tyytyväisyyteen.

Avainsanat	Hitsaus virheita- NDT menetelmät- Hitsausprocessi

Metropolia

Author Title Number of Page Date	Taoufik Tebbai Welding Inspection 69 pages 8 May2014
Degree	Bachelor of Engineering
Degree Programme	Mechanical Engineering
Specialisation option	Machine Design and Production technology
Instructor(s)	Joel Kontturi Project Engineer

The objective of this Bachelor's thesis is to describe welding inspection. The aim was to research that in metal and welding fields all perfectly-welded structures and products absolutely require a well- educated, active and honest welding inspector for the inspection process. A qualified welding inspector will ensure the quality of the company's products and keep the clients satisfied.

In my work experience it was found out that the welding inspector's qualification generally requires the control of NDT inspection, welding process, the work and the working environment, safety, physical fitness (vision), and the continuity of operations, A welding inspector training requirement for admission are as follows:
Machinery and metal engineering technician's qualification, an engineering or a Master of Science degree and a minimum of 5 years of work experience.

Non-destructive methods of NDT qualification practice designed to ensure each application used for the inspection Performance Much sufficient. Certification of compliance with a systematic approaches to documenting and accurately, setting new standards for inspection of documents. In this work, given the NDT methods of instructions related to radiography, ultrasound, penetrant for utilization.

As a result, it was discovered that a qualified welding inspector has a permanent control of the welding process as well as is able to monitor the instructed application of welding.
Properly performed welding reduces costs and increases quality and customer satisfaction.

Keywords	Welding Imperfection-NDT Methods-welding process

Contents

1 Introduction

In the fabrication industry it is common practice to employ Welding Inspectors to ensure that fabricated items meet minimum specified requirement and will be suitable for their intended applications. Employers need to ensure that Welding Inspectors have appropriate abilities, personal qualities and level of job knowledge in order to have confidence in their work. As a means of demonstrating this there are a number of internationally recognized schemes, under which a Welding Inspector may elect to become certified.

A competent Welding Inspector should possess a minimum level of relevant experience, and as such there are strict pre-examination experience experience requirement for the various examination grade. A proficient and efficient Welding Inspector would require a sound level of knowledge in a wide variety of quality related technologies employed within the many areas of the fabrication industry. As each sector of industry would rely more in specific processes and methods of manufacturing than others, it would be in impossible task hope to encompass them all in any great depth within this text, therefore the main aim has been to generalize, or simplify wherever possible.

In a typical welding Inspector working day a high proportion of time would be spent in the practical visual inspection and assessment of welds on fabrications, and as such this also forms a large part of the assessment procedure for most examination schemes. BS EN 970 (Non Destructive Examination of fusion Welds-Visual examination) is standard that gives guidance on on welding inspection practices as applied in Europe. [10]

The standard contains the following general information:

- Basic requirement for welding inspection personnel.
- Information about condition suitable for visual examination.
- Information about aids that may be needed/ helpful for inspection.
- Guidance about the stage when visual inspection is appropriate.
- Guidance on what information to include in examination records.

It could be generally stated that all welding inspector should be:

- Familiar with the standards, rules and specification relevant for the fabrication work being undertaken. (This may include National standards, Client standards and the company s own in –house standards)
- Informed about the welding processes/procedures to be used in production.
- Of high near visual acuity, in accordance with the applied schemes or standard. This should also be checked periodically.

The important quality/characteristics that the proficient Welding Inspectors are expected to have include:

- Honesty
- A good standard of literacy and numeracy
- A good level of general fitness
- A good long patience

Welding inspection is a job that demands the highest level of integrity, professionalism, competence, confidence and commitment, if it is to be carried out effectively. Practical experience of welding inspection in the fabrication in the industry together with recognised qualification in Welding Inspection is a route towards satisfying the requirement for competency.

The scope of work of the welding Inspector can be very wide and varied, however, there are number of topics that are common to most areas of industry, i.e. most fabrications are produced from drawings, and it is the duty of the welding inspector to check that correct drawings and revisions have been issued for during fabrication.

The duty of Welding inspector are an important list of tasks or check that need to be carried out by the inspector, ensuring the job is completed to a level of quality specified. These tasks or checks are generally directed in the applied application standard. [10]

A typical list of a welding Inspector's duties may be produced which for simplicity can be initially grouped into 3 specific areas:

1. Before Welding
2. During Welding
3. After Welding and Repairs

1.1 Before welding.

1.1.1 Safety

Ensure that all operations are carried out in complete compliance with local, company, or national safety legislation (i.e. permits to work are in place).

1.1.2 Documentation

Documentation is issued to relevant parties as checking specification, drawing, welding procedure specification and welder approvals validate certificate of calibration, material and consumable certification.

1.1.3 Welding Process and ancillaries

Welding equipment and all related ancillaries should be checked. (Cables, regulator, ovens, quivers etc.).

1.1.4 Incoming consumables

Pipe/plat and welding consumables should be checked for size, condition, specification and storage.

1.1.5 Marking out preparation &set up

- Correct method for cutting weld preparation should be checked. (pre-heat for thermal cutting if applicable)

- Correct preparation should be checked (relevant bevel angles, root face, root gap, root radius, land, etc)

- Correct pre-welding distortion control should be checked. (Tacking, Bridging, jigs, line up clamps, etc)

- Correct level and method of pre-heat applied to tack welding should be checked

- All tack welding to be monitored and inspected. (Feathering of task may be required) [10]

1.1.6 During Welding

Welding inspector should control Weather condition, Pre-heat values,
In process distortion control and consumable control, welding process and all related variable parameters. (Voltage, amperage, travel speed, etc), Welding or purging gases. (Type, pressure flow and control method), Welding condition for root run / hot pass and all subsequent run, and inter-run cleaning) and Minimum or maximum inter pass temperatures.

1.1.7 After welding

- visual inspection of the welding joint should be carried out

- NDT requirements should be checked

- repairs from assessment of visual or NDT report should be identified

- Post weld heat treatment PWHT (Heating method and temperature recording system)

- Re-inspect with NDE/NDT after PWHT. (IF applicable)

1.1.8 Repairs

Submission of inspection report, and all related documents to the Q/C department require:

- Excavation procedure. (Approval and execution)
- Approval of the NDT procedures (For assessment of complete defect removal)
- Execution of approval re-welding procedures.
- Re-inspect the repair areas with visual inspection and approval NDT method

Good Welding Inspectors should carry out their duties competently, use our authority wisely and be constantly aware of their responsibilities.

The main responsibilities of a Welding Inspector are:

- To observe all relevant action to weld quality throughout production. This will include a final visual inspection of the weld areas.
- To record, or log all production inspection points relevant to quality, including a final map and report sheet showing all identified welding imperfections.
- To compare all reported information with the acceptance level/criteria and clauses within the applied application standard.

Submit a final inspection report of your finding to the QA/QC department for analysis and any remedial actions. [10]

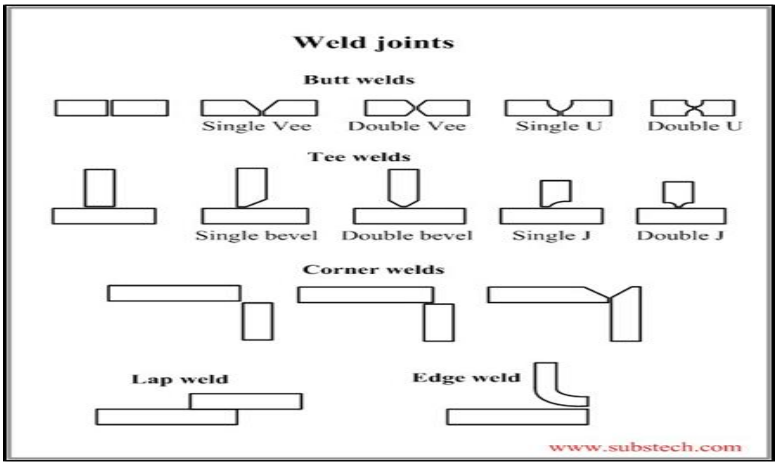
2 Welding Terms and Definitions

2.1 Welding joints and types

A Weld is a union of materials, produced by heat and /or pressure.

A joint is a configuration of members (To be welded). A Weld preparation is preparing a joint to allow access & fusion through the joint.

Types of weld**:** Butt. Fillet, Spot, Seam, Slot Edge as shown in picture 1



Picture 1 welding joints [4]

Types of joint: Butts: T's laps. Open corner. Closed corners as shown in
Picture 1
Types of preparation**:** Bevel's, V's, J's, U's Single double sided

Preparation terms**:** Bevel angle. Included angle. Root face. Root gap. Root dius. Root landing.

2.2 Weld preparation

When welding, we need to fully fuse the entire width of the faces of both members. Mostly, we need to prepare or move metal from metal from the joint to allow access for the process, for full fusion of the faces. The purpose of welding preparation is to allow access for the welding process, penetration and fusion thought the complete area of the joint and its faces. The function of the root gap is to allow penetration.

2.2.1 Weldment terms

Weld face, Weld root, Fusion zone, Fusion boundary,
Heat affect zone (HAZ), Weld toes, Weld width.

2.2.2 Weld sizing (Butt):

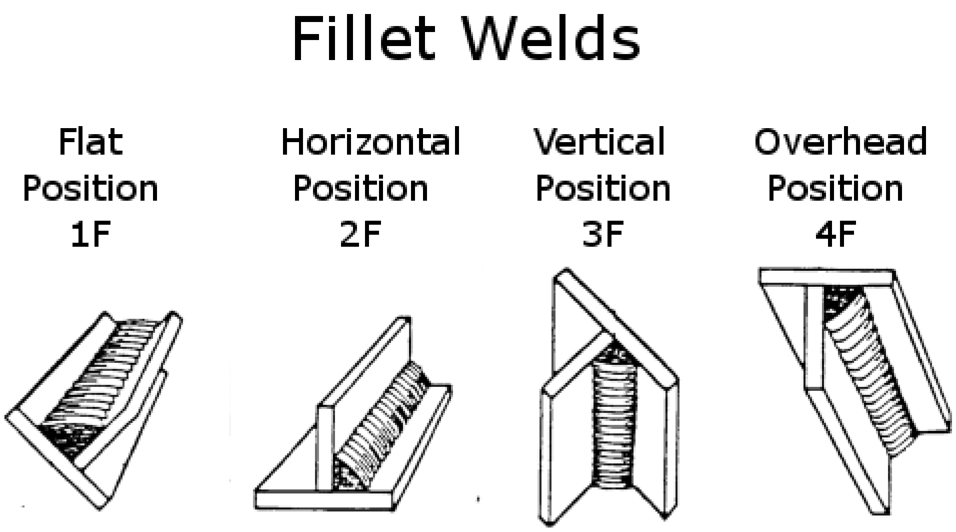
Design throat thickness (DTT)
Actual throat thickness (ATT)
Excess weld metal (Weld face)
Excess weld metal (root penetration bead)

2.2.3 Welding sizing (Fillets):

Design throat thickness (DTT)
Actual throat thickness (ATT)
Excess weld metal (Weld face)
Leg length

2.2.4 Welding position

There are essentially four different fundamental welding positions, namely flat, horizontal-vertical, overhead and vertical position. Vertical position welding can be carried out as vertical upward or vertical downward welding as shown in picture 2



Picture 2 fillet weld [4]

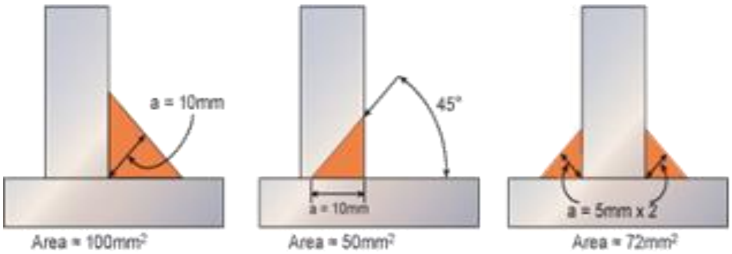
2.2.5 Weld sizing

2.2.6 Design Throat Thickness DTT

design throat thickness should be nominal or effective.

- “a”= a nominal design throat thickness (DTT)
- b = an effective design throat thickness (DTT) (Deep penetration fillets welds)

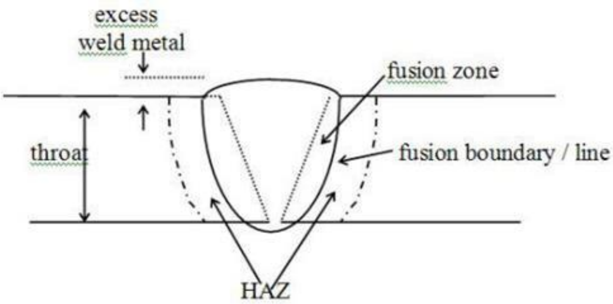
When using deep penetration welding processes with high current density it is possible to create deeper throat dimensions. This added line of fusion may be used in design calculation to carry stresses and is thus a major design advantage in reducing the overall weight of weld on large welded structures. [10] Look the picture 3



Picture 3 Design Throat Thickness DTT [15]

2.2.7 Excess weld metal

The excess weld metal can be measured by taking the measurable throat reading, then by deducting the design throat thickness. Look the picture 4



Picture 4 excess weld metal [15]

3 Welding Imperfection:

3.1 Welding imperfection Definition

Welding imperfection are discontinuities caused by the process of welding. As thing contain imperfection it is only when they fall outside of an applied (level of acceptance) that they should be termed as *defects,* as if present they may they render the product defective or unfit for its purpose. The closeness of tolerance in any applied level of acceptance depends largely upon the application and /or the level of quality required.

As all fusion weld can be considered as casting they may contain imperfections associated with the casting of metals. Plus any other particular imperfections associated with the specific welding process being used. Welded components may contain imperfection, which can be classified as following:

- Cracks
- Gas pores, cavity, pip
- Solid inclusion
- Lack of fusion
- Surface and profile
- Mechanical/ Surface damage
- Misalignment

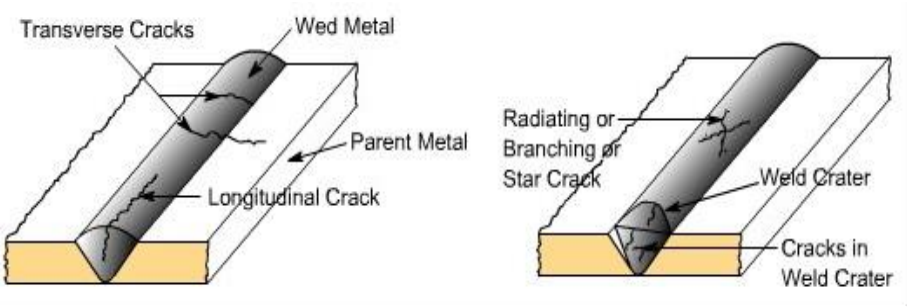
3.2 Cracks

Cracks sometimes occur in welded materials, and maybe caused by a great number of factor. Generally it can be stated that for any crack like imperfection to occur in a material as shown in pictures 6&7, there are 3 criteria that must be fulfilled:

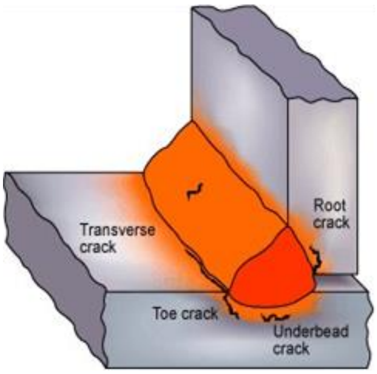
- A force
- Restraint
- A weakened structure

Typical types of hot and cold cracks: look the picture 6

- H2 Cracks
- Solidification
- Lamellar Tears



Pictures 5 cold crack [15]

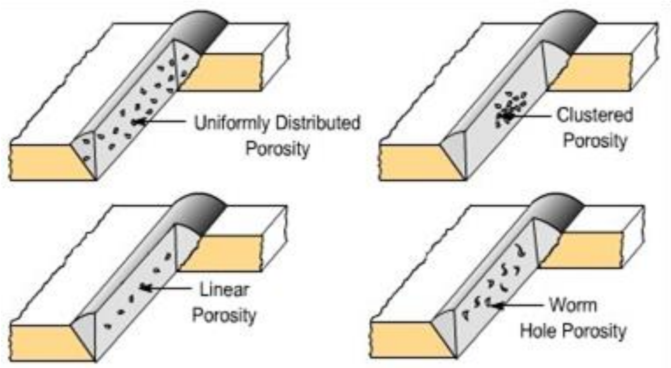


Picture 6 Root crack [4]

3.3 Gas pores, porosity, cavity pipes

Gas pores are singular gas filled cavities 1.5 mm diameter, created during solidification of the weld and the expulsion or evolution of gases from solution in solidifying weld metal.

They are generally spherical in appearance though they may extend to form elongated gas cavities or worm hole depending on the condition of solidification. This term used to describe an area of rounded of gas pores is porosity as shown in picture 7

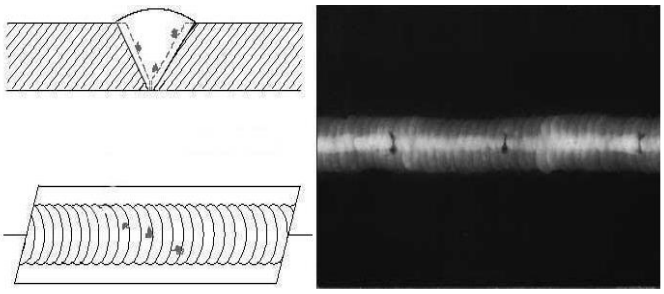


Picture 7 porosity [4]

3.4 Solid inclusions

Solid inclusion can be metallic or non-metallic that is trapped in the weld. The type of solid inclusion is really dependant on the welding process being used. In welding processes that use fluxes to form all required function of shielding and chemical cleaning, such as MMA/MAG and SAW, slag inclusion may occur. Other welding processes such as MIG/MAG and TIG use silicon, aluminium and other elements to de-oxidise the weld. These may form silica, aluminium inclusion. Any non metallic compounds may be trapped inside a weld. This may happen when slag trap, such as undercut have been formed. Slag traps are mostly caused by incorrect welding technique as shown in picture 8.
Lack of side wall fusion generally solid internal inclusions may be caused by:

- Lack of welder skill (incorrect welding technique)
- Incorrect parameter setting i.e. voltage, amperage speed of travel
- Magnetic arc blow
- Incorrect positional use of process, or consumable
- Incorrect inter-run cleaning



Picture 8 solid inclusion [15]

3.5 Lack of fusion

Lack of fusion imperfections, are defined as a lack of union between two adjacent areas of material. This may be accompanied or caused by other imperfection. Lack of fusion can be considered as serious imperfection, as like crack, they produce areas of high stress concentration. Lack of fusion may occur in the weld face area during positional welding caused by the action of gravity and incorrect use of processes. Lack of fusion may be found in welds where processes using high current have used as the arc may be deviated away from the fusion faces causing a lack of fusion in that area of weld. Lack of fusion may also be formed in the root area of the weld it may be found on one or both plat edges as shown in picture 9.

Lack of fusion imperfection may be caused by:

- Lack of welder skill (incorrect welding technique)
- Incorrect parameter setting i.e. voltage, amperage speed of travel
- Magnetic arc blow
- Incorrect positional use of process, or consumable
- Incorrect inter-run cleaning

Picture 9 lack of fusion [15]

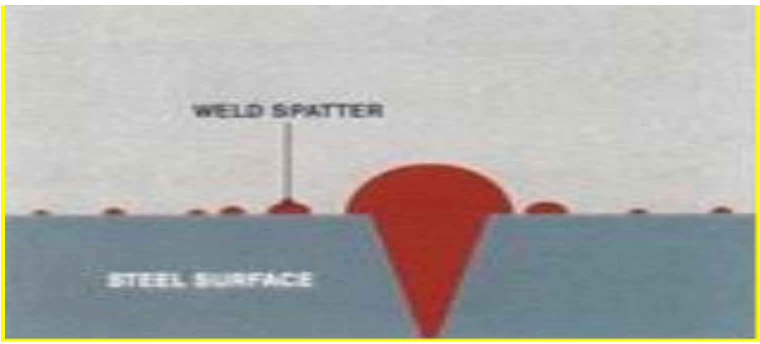
3.6 Surface and profile

Surface and profile imperfection are generally caused by poor welding technique. This includes the use incorrect welding parameters, electrod/blowpipe sizes or manipulation and joint set up. We have different imperfection of surface and profile as following:

3.6.1 Spatter

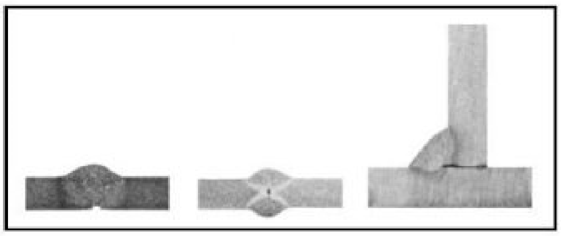
Spatter is not a major factor in lowering the weldments strength, though it may mask other imperfection, and should therefore be cleaned off before inspection as shown in picture 10

An incompletely Filled groove will bring the weld below the **DTT** (Design Throat Thickness) and may also cause a high stress concentration to occur.



Picture 10 weld spatter [15]

Lack of root fusion may cause serious stress concentrations to occur in the root area of the weld. It may be caused by a poor welding technique. Look the picture11

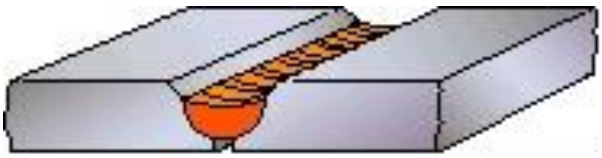


Picture 11 lack of root fusion [15]

Bulbous contour is an imperfection as it sharp stress concentration at the toes of individual passes and may also contribute to overall poor toe blend.

Arc strikes, Stray-arcing, or Stray flush may cause many problems including cracks to occur.

Incomplete root penetration may be caused by too small a root gap. Insufficient amperage or poor welding technique. It may be also appear in welding at the end of poorly dressed tack weld. Incomplete root fusion as shown in pictures 12



Pictures 12 incomplete root penetration [4]

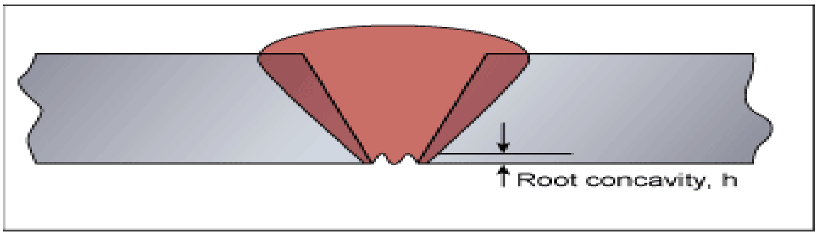
3.7 Undercut imperfection

Undercut can be defined as a depression at the toe of a weld in a previous deposited weld metal caused by welding. Undercut is principally caused by an incorrect welding technique, including to high a welding current, to slow a travel speed in conjunction with the welding position **2F/2G or PB/PC**. It is often found in the top of fillet welds. Undercut can be considered a serious imperfection as shown in pictures13

Pictures 13 undercut imperfection [4]

3.8 Root concavity

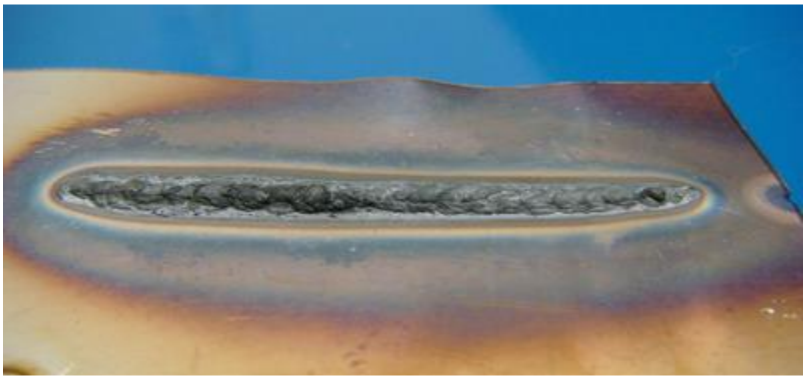
This may be caused when used too high a gas backing pressure in purping. It may also be produced when welding too large a root gap and depositing too thin a root bead, or too large a hot pass which may pull back the root bead through contractional stresses as shown in picture 14



Picture 14 root concavity [4]

3.9 Root oxidation

Root oxidation may take place when welding re-active metals such as stainless steel with contaminated or inadequate purging gas flow as shown in picture 15.



Picture 15 images for root oxidation [15]

3.10 Misalignment

They are two main forms of misalignment in plate material

3.10.1 Linear misalignment

Linear misalignment can be controlled by the correct use of the weld set up technique. It is measured in millimetres.

3.10.2 Angular misalignment

Angular misalignment may be controlled by the correct application of distortion control technique and it is measured in degree. Look the picture 16

Picture 16 misalignment [4]

3.11 Mechanical/Surface damage

This can be defined as any material surface damage caused during the manufacturing or handling process in service condition like grinding-hammering- chipping- corrosion- chiselling etc as shown in picture 17.[10]

Picture 17 mechanical damage [15]

4 Welding Testing

Destructive testing is generally carried out to ensure that the required levels of certain mechanical proprieties have been achieved. When metals have been welded, the mechanical properties of the plates may have changed in the HAZ due to the thermal effects of the welding process. [10]

4.1 Hardness and Micro hardness Testing

Hardness and Micro hardness Testing is the measure of how resistant solid matter is to various kinds of permanent shape change when a force is applied. Methods include: Rockwell standard testing, Rockwell superficial testing, Knoop & Vickers micro hardness testing, and Brinell hardness testing.

- **Tensile Testing** subjects a sample to uniaxial tension until it fails. Element tensile testing capabilities include: wedge tensile testing, axial tensile testing, weld tensile testing, castings tensile testing, and elevated temperature tensile, tensile testing for machined specimens, full-size tensile testing and yield tensile, plus heat treatment capabilities.

- **Torque Testing** is the tendency of a force to rotate an object about an axis. Element can perform torque testing on most hardware and fastener products.

- **Fatigue Testing** is performed on parts and materials to simulate the progressive and localized structural damage that occurs when a material is subjected to cyclic loading. Element's fatigue testing methods include: fracture toughness testing, a measure of the fracture resistance of a material containing a crack; rotating beam fatigue testing; strain controlled axial fatigue testing; stress controlled axial fatigue testing, and da/dn testing (crack propagation rate).

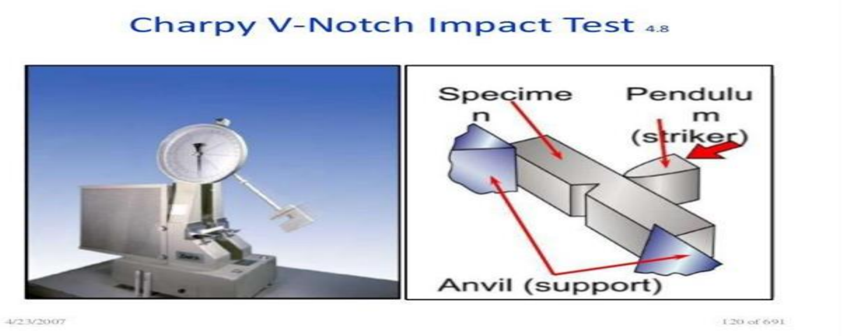
- **Charpy Impact Testing**: The Charpy impact test, also known as the Charpy v-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture. Element conducts sub-size Charpy impact testing and standard Charpy impact testing. Look the picture 18

- **Bend Testing** determines the ductility or the strength of a material by bending the material over a given radius. Element performs bolt bend testing, weld bend testing, and raw materials bend testing.

- **Proof Load Testing** is often used interchangeably with yield strength; it refers to the tension- applied load that a test sample must support without evidence of deformation. Proof load testing can be done on nuts, bolts, components, and assembled products. Methods include: tension testing, compression testing.

- **Shear Testing:** Shear strength measures a material's response to shear loading, a force that tends to produce a sliding failure on a material along a plane that is parallel to the direction of the force. Element performs shear testing on bolts, rivets, pins, and other products: single shear testing, double shear testing, and washer testing and other testing.

- **Other mechanical testing capabilities** include mechanical durability, experimental stress analysis, flow measurement, fatigue analysis, structural testing, and pressure cycling.



Picture 18 images charpy v-notch impact test [15]

4.2 Qualitative and Quantitative

The following mechanical tests have units and are termed quantitative test to measure properties

- Tensile test (Transverse welded join, All weld metal)
- Toughness testing (Charpy, Izod, CTOD)
- Hardness tests (Brinell, Rockwell, Vickers)

The following mechanical tests have no units and are termed qualitative test for assessing joint quality

- Macro testing
- Bend testing
- Fillet weld fracture testing
- Butt weld nick-break testing

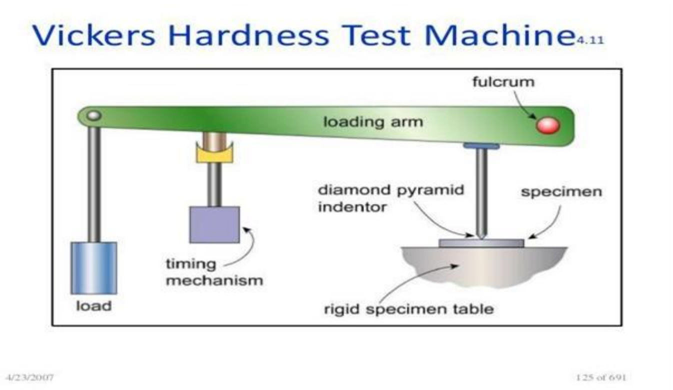
5 Hardness Testing

Hardness test, the material is held between a steel anvil and a pointed indenter. A load is applied to the indenter, and the distance the indenter travels into the material is measured. This measurement provides a hardness value

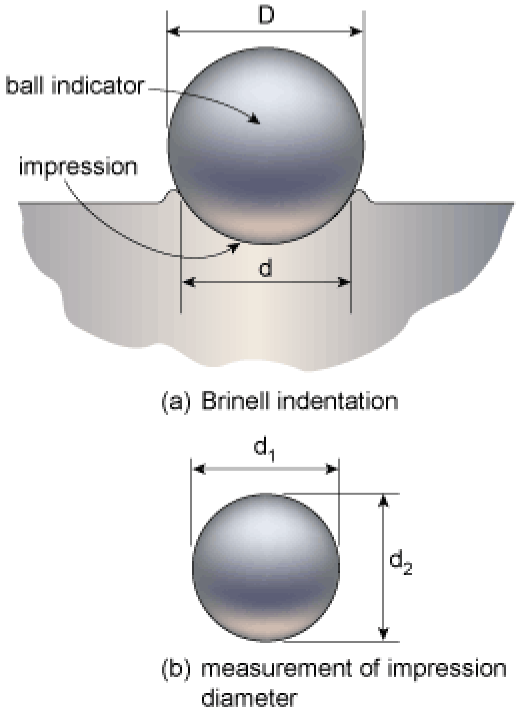
to the material. See Vickers test in picture 20, Koop test, Brinell test in picture 21, and Rockwell test in picture 19.

The Objective:

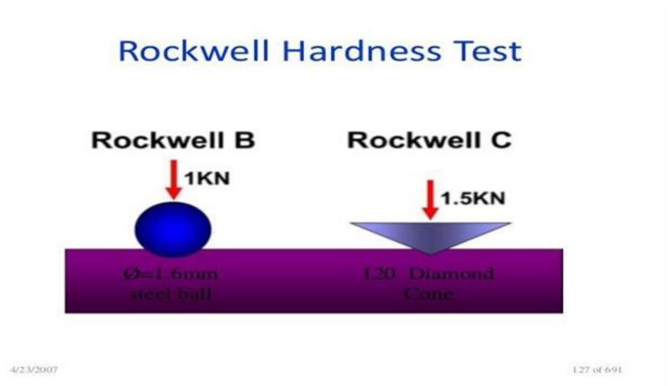
- To understand the importance of hardness test in engineering
- To learn how to use Rockwell hardness tester
- To understand the different hardening mechanisms in different material systems and effect on hardness values.
- To understand the significance of Engineering Standards



Picture 19 image Vickers test machine [15]



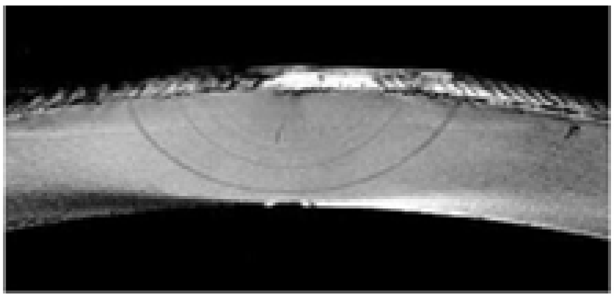
Picture 20 image Brinell test [15]



Picture 21 Rockwell hardness [4]

5.1 Fatigue Fracture

It has been recognized that a metal subjected to a repetitive or fluctuating stress will fail at a stress much lower than that required to cause failure on a single application of load. Failures occurring under conditions of dynamic loading are called a fatigue failure as shown in picture 22.



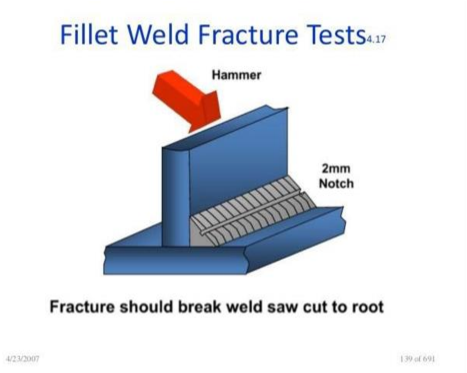
Picture 22 Fatigue failure [4]

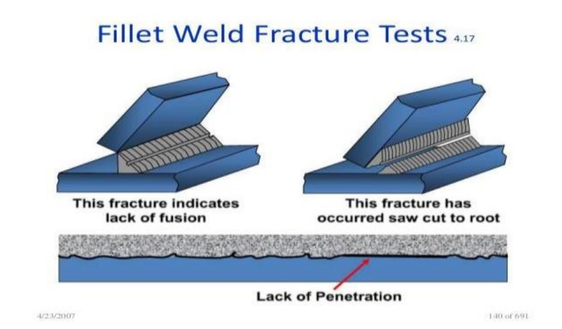
Fatigue failure is characterized by three stages:

1. Crack Initiation
2. Crack Propagation
3. Final Fracture

5.2 Filled Weld Fracture Test

A fillet weld fracture test is normally only carried out during a welder approval test. The specimen is normally cut by hacksaw through the weld to depth usually 1-2 mm stated in the standard. It is then held in a vice and fractured with a hammer blow from the rear. After fracture has been made both surfaces are then carefully inspected for imperfections. Look 2 pictures 23

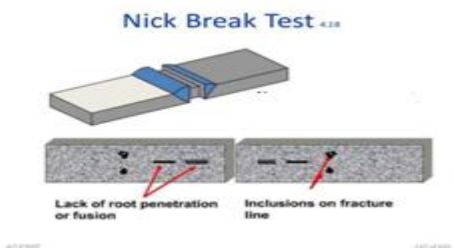




Pictures 23 fillet weld fracture [4]

5.2.1 Filled weld break test

Nick-break test used to assess root penetration and fusion in double-sided butt weld, and the internal faces of single sided butt welds. A Nick –break test is normally carried out during a welder approval test. The specimen is normally cut y hacksaw through the weld faces to a depth stated in the standard. It may then be held in a vice and fractured with a hammer blow from above , or placed in tension and stressed too fracture. Once fracture has occurred both fracture faces are then turned horizontally through 90˚ and may then be inspected for imperfections along the fracture faces. Look the picture 24



Picture 24 Nick-Break Test [15]

6 Welding Procedure Specification

6.1 Introduction

Welding procedure is a systematic method that is used to repeatedly produce sound weld. The use of welding as a process or method of joining materials in engineering has been long established, with new technique and process being developed from on-going research and development on a regular basis. There are over 100 recognised welding or thermal joining processes of which many are either fully automated or mechanised, requiring little assistance from the welder/operator and some that require a very high level of manual input in both skill and dexterity. For each welding process there are a number of important variable parameters that may be adjusted to suit different applications, but must also be kept within specified limits to be able to produce welds of parameters as essential variables.

7 Welding process

A welding process is special equipment used with method, for producing weld. Welding processes may be classified using various methods, such as process that use pressure and those which not, but may also be classified as fusion or solid phase. They are 4 main requirements of any fusion welding processes:

- Heating
- Protection
- Cleaning
- Adequate properties

7.1 Fusion welding

The weld requires melting/mixing and re-solidification. This system would thus the resistance welding process within this group.

7.2 Solid phase /state welding process

The weld is made in the plastic condition.

8 Procedure Qualification Record – PQR

A WPQR can support several WPS under validity areas. WPQR preparation and tests must be conducted and approved under supervision of Third Party Inspection Bodies and WPQR must be in compliance with standard of the job carried out. For jobs apart from ASME Code, related standard must be taken as a basis. For example, for jobs under EN norm, WPQR that complies with EN standard will be prepared. The welding terminology that will be used must be appropriate to manufacturing standard.

8.1 Welder Certificate

In the welded manufactures, welding must be performed by a welder who has absolutely this qualification. For certification of this, welders will be tested according to ACME SEC. IX or EN 287-1 standard in compliance with project standard and will have a certificate and badge that covers the welding specifications.

Tests of welders must be conducted under supervision of Independent Inspection Bodies, then certificates must be given by these bodies. Welders who do not have such a certificate or whose certificate is expired, then before the project, they must be re-taken to test in supervision of authorized Inspection Company.

In certificate of every welder, there must a special cold seal mark. This seal must be affixed next to welding job carried out by welder. Welder Certificate must be in compliance with the job carried out. For jobs apart from ASME Code, related standard must be taken as a basis. For example, for jobs under EN norm, Welder Certificate that complies with EN 287-1 standard will be prepared. The welding terminology that will be used must be appropriate to manufacture standard. EN welding terminology definitely should not be used in US manufacturing standards, and US terminology in EN standards. [9]

9 Material Inspection

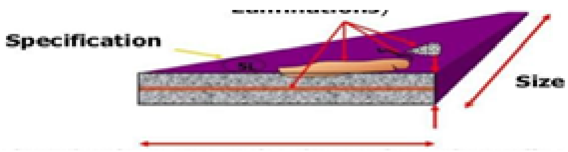
One of the most important items to consider is Traceability.
The materials are of little use we cannot, by use of an effective QA system trace them from specification and purchase order to final documentation package handed over to the client.

All materials arriving on site should be inspected for:

- Size / dimensions
- Condition (as shown in pictures 25-26)
- Type / specification

In addition other elements may need to be considered depending on the materials form or shape.

Picture 25 pipe inspection (9)



Picture 26 plate inspection (9)

10 Code and Standards

A code of practice is generally considered as legally binding document containing all obligatory rules required to design, build and test a specific product. A standard will generally contain, or refer to all the relevant optional and mandatory manufacturing, testing and measuring data.

10.1 A code of practice

A set of law's or rules that shall be following when providing a service or product.

10.2 An application standard

A level of quality or specification too which something may be tested. It would use codes and standards to manufacture many things that have been built many times before. The most major application codes and standards contain 3 majors areas, which are dedicated to the

1. Design
2. Manufacturing
3. Testing

10.3 Typical content of Manufacturing Standard

Most manufacturing standards can be basically divided into 3 areas, these areas well contain similar types of instructions, data, or information referenced to the production of that which standard covers.

10.4 Welding Symbols on Drawing

It is essential that a competent welding inspector can interpret weld symbol, as a large proportion of the inspector's time may spent checking that the welder is completing the weld in accordance with the approved fabrication drawing.

10.4.1 Weld sizing

In order that the correct size of weld can be applied, it is common to find numbers to either the left or to the right of the symbol.
For fillet welds, numbers to the left of the symbol indicate the design throat thickness, leg length, or both design throat thickness and leg length requirements. Figure 1 gives examples of symbols used in different Standards.

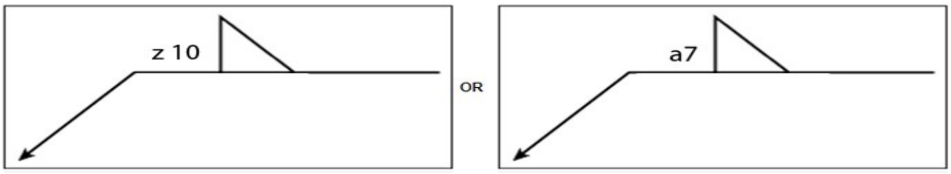


Fig1 For fillet welds [15]

Superseded BS499 Pt 2 gives
a=Throat
b = leg length
ISO 2553/EN 22553 requirements
Z=leg length
a= Throat if nominal
s = penetration throat thickness
For butt joints and welds, an S with a number to the left of a symbol refers to the depth of penetration as shown in *Fig.2*

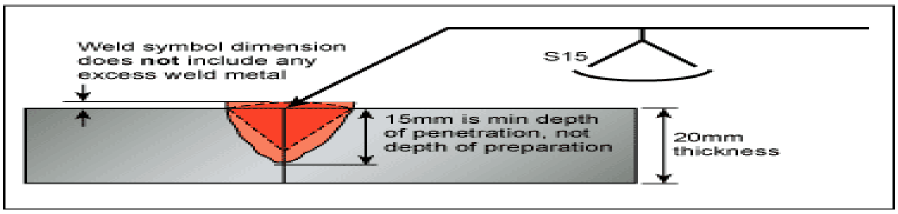


Fig 2 filled weld [4]

When there are no specific dimensional requirements specified for butt welds on a drawing using weld symbols, it would normally be assumed that the requirement is for a full penetration butt weld (*Fig. 3*).

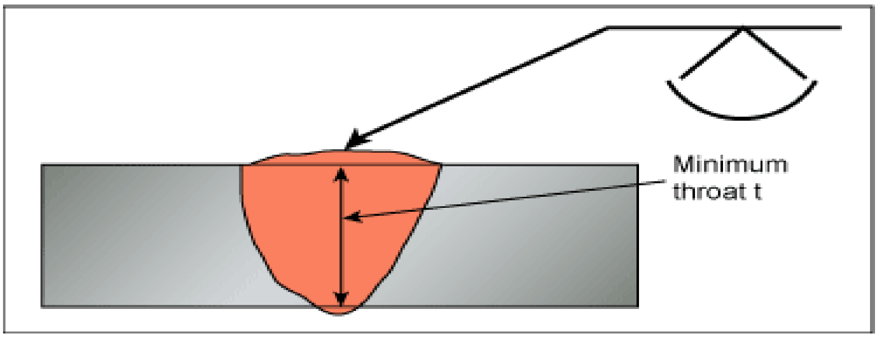


Fig 3 butt weld [4]

Numbers to the right of a symbol or symbols relate to the longitudinal dimension of welds, *eg* for fillets, the number of welds, weld length and weld spacing for non-continuous welds, as *Fig. 4*.

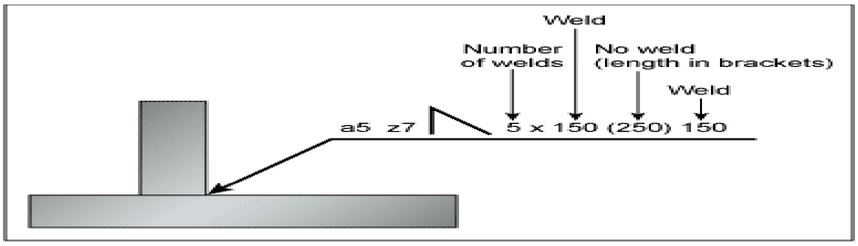


Fig 4 non-continuous welds [4]

On fillet welded joints made from both sides, a staggered weld can be shown
by placing a 'Z' through the reference line (*Fig. 5*).

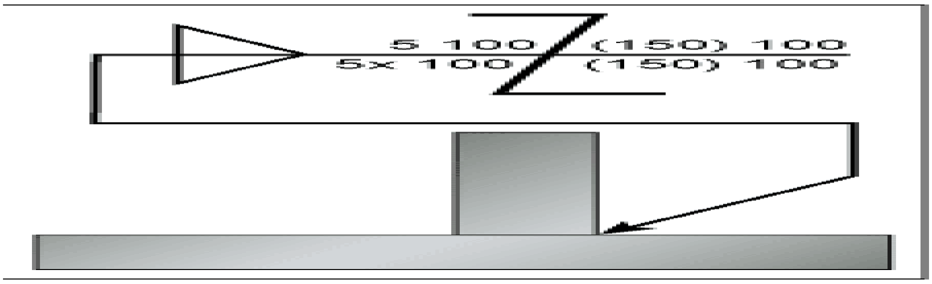


Fig 5 filled welded joints both side [4]

10.4.2 Supplementary symbols

Weld symbols indicate the type of preparation to use or the weld type. However, there may still be occasions where other information is required. The basic information can therefore be added to in order to provide further details as shown in *Figs.6, 7 and 8*.

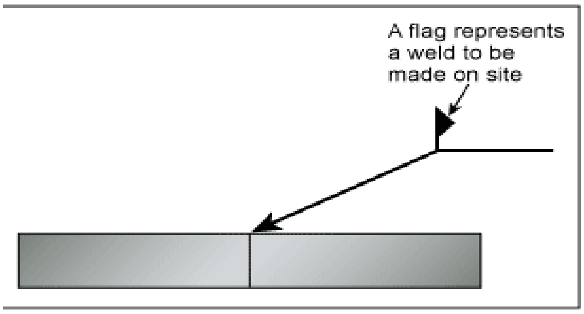


Fig 6 flag weld [4]

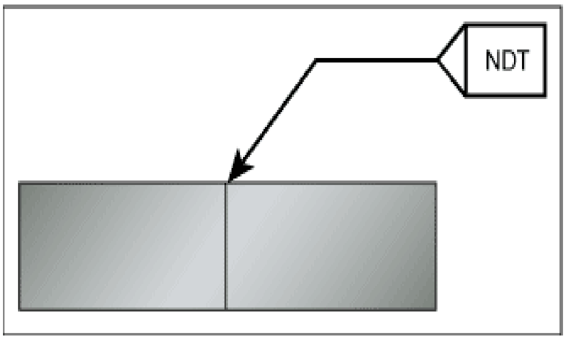


Fig 7 NDT symbol [4]

- **Weld all round**

For a Rectangular Hollow Section (RHS) welded to a plate, see Fig 8

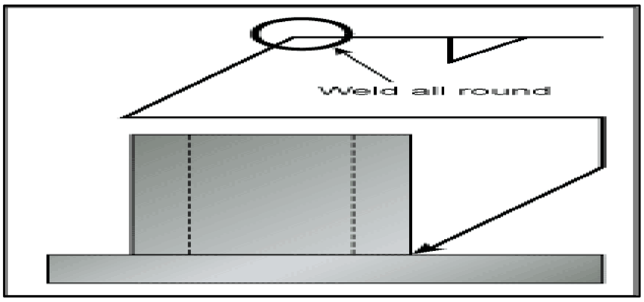


Fig 8 weld all round [4]

- **Weld in the field or on site**

The box attached to the arrow can be used to contain, or point to, other information.

- **Welding process type**

ISO 4063 gives welding processes specific reference numbers. As shown in Fig.9 the appropriate process number is placed in the tail of the arrow. Other processes are given a unique number. In this example, 135 refer to MAG welding. Fig 9

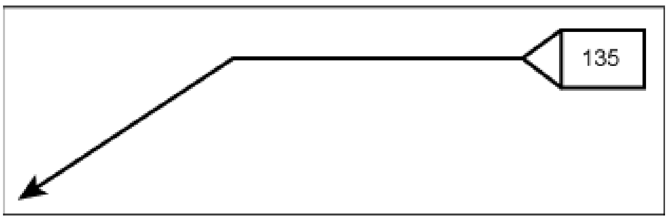


Fig 9 welding process symbol [4]

There are a number of additional symbols given in the Standards (*eg* ISO 22553) which refer to additional welding or joint requirements. *Figure 10* shows the requirement for a sealing run.

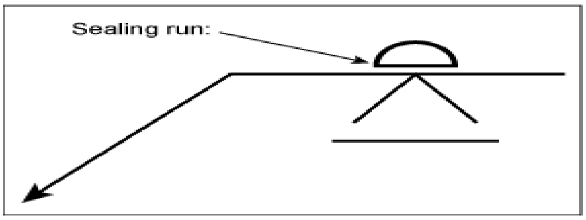


Fig 10 sealing run symbol [4]

- ***Compound joints/welds***

A compound weld could be a 'T' butt weld which requires fillet welds to be added to increase the throat thickness as shown in *Fig. 11*.

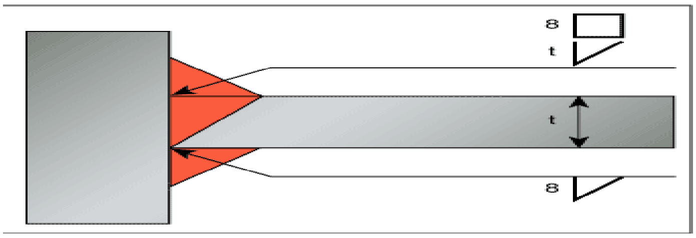


Fig 11 Compound weld [4]

- **The broken reference line**

The main feature that distinguishes weld symbol standards is that for ISO 2553 and BS EN 22553, there is an additional feature of a broken reference line. Look the Fig 12

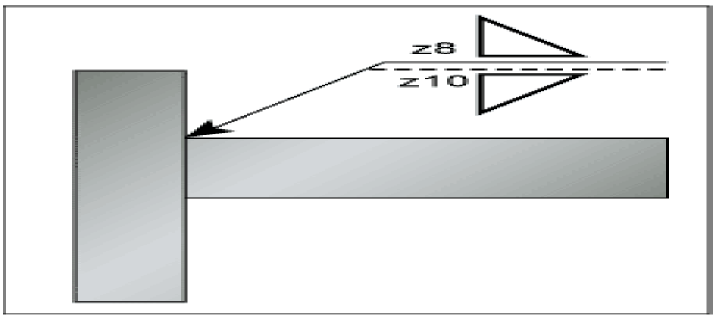


Fig 12 the broken reference line [4]

This method is used when a weldment or weld preparation needs to be specified on the 'other side' of the arrow as shown in *Fig. 12*.

Fig 12

Any symbol that is used to show a joint or weld type feature on the other side of the arrow line is always placed on a dotted line.

BS 499 and AWS require symbols to be placed above the reference line (which indicate the other side) or below the reference line (indicating the arrow side).

10.4.3 Summary

Weld symbols are a very useful way of communicating welding requirements from the design office to the shop floor.

It is essential that the 'rules' of the standard used are correctly applied by drawing office personnel. However, it is also important that shop floor personnel are able to read and understand the details of weld symbols.

Much of this requirement can be met by reference to the standard being used within the organisation and by the drawing office personnel considering the needs of the end user such as the welders, welding supervisors, welding inspection personnel and welding engineers in order to minimise costly mistakes due to misinterpretation.

Training of all personnel in the correct use of weld symbol specifications also plays an important role in ensuring that weld symbols are both correctly applied and correctly read. [10]

11 Welding consumables

Welding consumables are any products that are used up in the production of weldability Welding consumables may be:

- Covered electrodes, filler wires and electrodes wires.
- Shielding or oxy-fuel gases.
- Separately supplied fluxes.
- Fusible inserts.

When inspecting welding consumables arriving at site it is important that they are inspected for the following:

1) Size
2) Type or Specification
3) Condition
4) Storage

11.1 MMA Welding Consumables

The three main electrodes covering types used in MMA welding

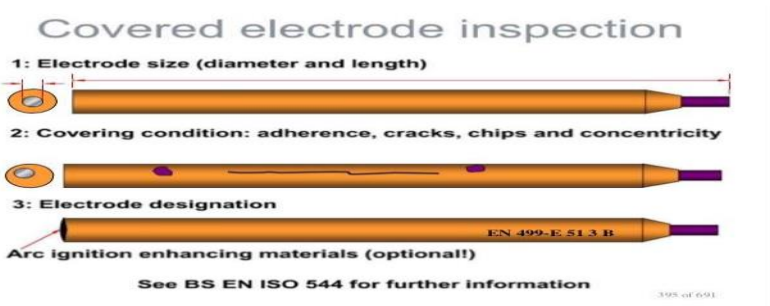
- Cellulosic-deep penetration/fusion
- Rutile -general purpose
- Basic – low hydrogen

11.1.1 Welding of consumables for MMA

- Consist of a core wire typically between 350-450 mm in length and from 2.5mm-6mm in diameter. The wire is covered with an extruded flux coating; core wire is generally of a low quality rimming steel.
- The weld quality is refined by the addition of alloying and refining agents in the flux coating, the flux coating contains also many elements and compounds that all have a variety of functions during welding

11.1.2 Function of the Electrode Covering:

- To facilitate arc ignition and give arc stability
- To generate gas for shielding the arc and molten metal from air contamination
- To de-oxidise the weld for metal and flux impurities into the slag
- To form a protective slag blanket over the solidifying and cooling weld metal
- To provide alloying elements to give the required weld metal properties
- To aid positional welding (slag design to have suitable freezing temperatures to support the molten weld metal)
- To control hydrogen contents in the weld (basic type). Look the pictures 27



Picture 27 covered electrode [4]

11.2 TIG consumables

Welding consumables for TIG:

- Filler wires, Shielding gases, tungsten electrodes (non- consumable).
- Filler wires of different materials composition and variable diameter available in standard length, with applicable code stamped for identification.
- Steel filler wires of very high quality, with copper coating to resist corrosion.
- Shielding gases mainly Argon and Helium, usually of highest purity (99.9%).

11.3 TIG Welding Rods:

- supplied in cardboard/plastic tubes
- must be kept clean and free from oil and dust
- Might require degreasing.

11.3.1 Argon Ar

- Low cost and greater availability heavier than air-lower flow rates than Helium.
- Low thermal conductivity -wide top bead profile and low ionisation potential - easier arc starting, better arc stability with AC, cleaning effect.
- For the same arc current produce less heat than helium- reduced penetration, wider HAZ.
- to obtain the same arc power, argon requires a higher current- increased undercut

11.3.2 Helium He

- Costly and lower availability than Argon and lighter than air- requires a higher flow rate compared with argon (2-3 times).
- Higher ionisation potential- poor arc stability with AC. Less forgiving for manual welding.
- for the same arc current produce more heat than argon- increased penetration, welding of metals with high melting point or thermal conductivity.
- to obtain the same arc power, helium require a lower current -no undercut

11.3.3 Hydrogen H_2

- Not an inert gas- not used as a primary shielding gas.
- increasing the heat input- faster travel speed and increased penetration
  better wetting action- improved bead profile and produce a cleaner weld bead surface.

- added to argon (up to 5%)- only for austenitic stainless steel and nickel alloys
- Flammable and explosive.

11.3.4 Nitrogen N_2

Nitrogen is a colourless, odourless, and tasteless gas which forms 78 percent of the earth's atmosphere (by volume). It is non-flammable, does not support combustion, and is slightly lighter than air. Nitrogen is inert except at arc welding temperatures, where it will react with some metals, such as aluminium, magnesium, and titanium. It is not recommended as a primary shielding gas with GMAW, but is commonly applied as an assist gas with laser cutting on stainless steels. It can be used in combination with other gases for some welding applications and is also widely used in plasma and laser cutting. [6]

12 Welding consumables

12.1 MIG/MAG Consumables

Welding consumables for MMA consist of a core wire typically between 350 and 450 mm length and from 2.5-6 mm diameter. Other length and diameter are also available. The wire is covered with an extruded flux coating. The core wire is generally of low quality steel as the weld can be considered as a casting and therefore the weld can be refined by the addition of cleaning or refining agent in the flux coating. The flux coating contains many elements and compounds that all have a variety of jobs during welding.

12.2 SAW Consumables

Consumable for submerged arc welding consist of an electrode wire and flux. Electrode wires are normally of high quality and for welding C/Mn steels are generally graded on their increasing carbon and manganese content level of de-oxidation.
Electrode wire for welding other alloy steel is generally graded by chemical composition in a table in a similar way to MIG and TIG electrode wires. Fluxes for submerged Arc welding are graded by their manufacture and composition.

12.2.1 Welding flux

Fused fluxes are mixed together and baked at very high temperature > 1000˚C, where all the component become fused together. When cooled the resultant mass resembles a sheet of coloured glass, which is then pulverised into small particles.

12.2.2 Agglomerated fluxes

Agglomerated fluxes on the other hand are a mixture of compound that are baked at a much lower temperature and are essentially bonded together by bonding agent into small particle. Look the picture 28

Picture 28 image of welding flux [4]

13 NON-DESTRUCTIVE TESTING

NDT or Non Destructive Testing may be used as a means to evaluate the quality of a component by assessing its internal and external integrity, but without destroyed it.
They are many methods of NDT some of which require a very level of skill both in application and analysis and therefore NDT operators for these methods require a high degree of training and experience to apply them successfully.

13.1 Surface crack detection

- Liquid penetration (PT or dry-penetrant).
- Magnetic particle inspection (MT or MPI).

13.1.1 Volumetric & Planar Inspection

- Ultrasonic’s (UT).
- Radiography (RT).

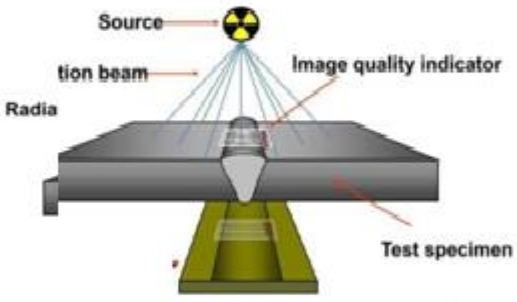
Each technique has advantages& disadvantages with respect to:

- Technical capability and cost

Note: The choice of NDT techniques is based on consideration of these advantages and disadvantages [3]

13.2 Radiographic testing [3]

As shown in picture 29



Picture 29 image of Radiographic Testing [15]

13.3 Ultrasound testing

Ultrasonic Testing (UT) uses high frequency sound energy to conduct examinations and make measurements. Ultrasonic inspection can be used for flaw detection/evaluation, dimensional measurements, material characterization, and more. To illustrate the general inspection principle, a typical pulse/echo inspection configuration as illustrated below will be used.

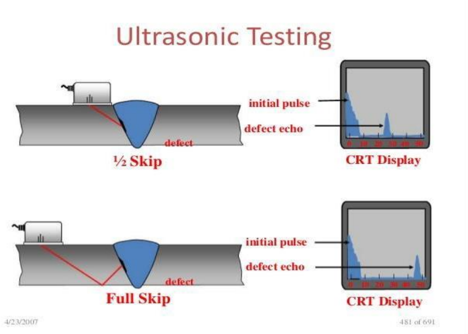
A typical UT inspection system consists of several functional units, such as the pulser/receiver, transducer, and display devices. A pulser/receiver is an electronic device that can produce high voltage electrical pulses. Driven by the pulser, the transducer generates high frequency ultrasonic energy. The sound energy is introduced and propagates through the materials in the form of waves. When there is a discontinuity (such as a crack) in the wave path, part of the energy will be reflected back from the flaw surface. The reflected wave signal is transformed into an electrical signal by the transducer and is displayed on a screen. In the applet below, the reflected signal strength is displayed versus the time from signal generation to when an echo was received. Signal travel time can be directly related to the distance that the signal travelled. From the signal, information about the reflector location, size, orientation and other features can sometimes be gained. [3] Look the pictures

Ultrasonic Inspection is a very useful and versatile NDT method. Some of the advantages of ultrasonic inspection that are often cited include:

- It is sensitive to both surface and subsurface discontinuities.
- The depth of penetration for flaw detection or measurement is superior to other NDT methods.
- Only single-sided access is needed when the pulse-echo technique is used.
- It is highly accurate in determining reflector position and estimating size and shape.
- Minimal part preparation is required.
- Electronic equipment provides instantaneous results.
- Detailed images can be produced with automated systems.
- It has other uses, such as thickness measurement, in addition to flaw detection.

As with all NDT methods, ultrasonic inspection also has its limitations, which include:

- Surface must be accessible to transmit ultrasound.
- Skill and training is more extensive than with some other methods.
- It normally requires a coupling medium to promote the transfer of sound energy into the test specimen.
- Materials that are rough, irregular in shape, very small, exceptionally thin or not homogeneous are difficult to inspect.
- Cast iron and other coarse grained materials are difficult to inspect due to low sound transmission and high signal noise.
- Linear defects oriented parallel to the sound beam may go undetected.
- Reference standards are required for both equipment calibration and the characterization of flaws. [2] look the picture 30



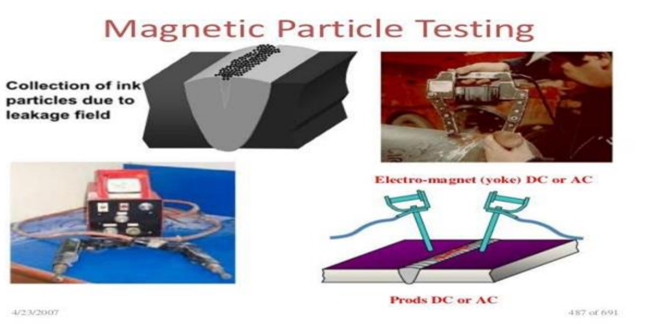
Picture 30 Ultrasonic Testing [15]

13.4 Magnetic testing

Magnetic particle inspection (MPI) is a non-destructive testing method used for defect detection. MPI is fast and relatively easy to apply, and part surface preparation is not as critical as it is for some other NDT methods. These characteristics make MPI one of the most widely utilized non-destructive testing methods.

MPI uses magnetic fields and small magnetic particles (i.e. iron filings) to detect flaws in components. The only requirement from an inspect ability standpoint is that the component being inspected must be made of a ferromagnetic material such as iron, nickel, cobalt, or some of their alloys. Ferromagnetic materials are materials that can be magnetized to a level that will allow the inspection to be effective.

The method is used to inspect a variety of product forms including castings, forgings, and weldments. Many different industries use magnetic particle inspection for determining a component's fitness-for- use. Some examples of industries that use magnetic particle inspection are the structural steel, automotive, petrochemical, power generation, and aerospace industries. Underwater inspection is another area where magnetic particle inspection may be used to test items such as offshore structures and underwater pipelines. [8] Look the pictures 31



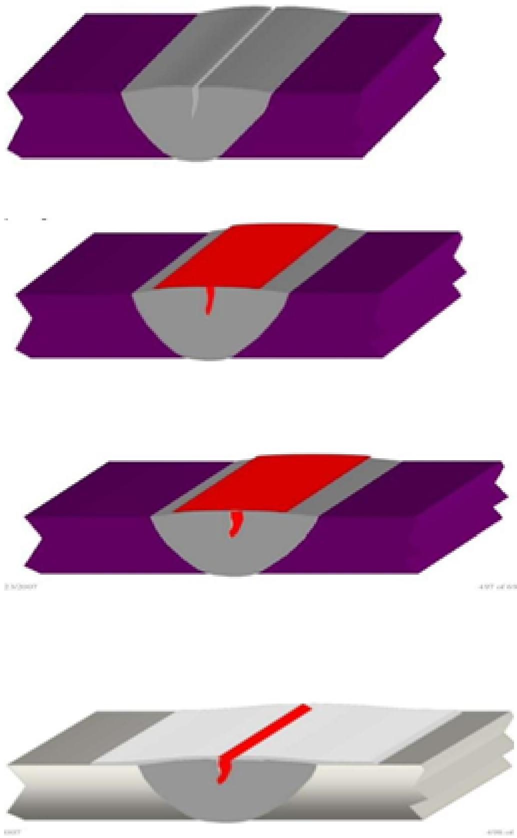
Picture 31 Magnetic testing MT [15]

13.5 Penetrant testing

The penetrant materials used today are much more sophisticated than the kerosene and whiting first used by railroad inspectors near the turn of the 20th century. Today's penetrants are carefully formulated to produce the level of sensitivity desired by the inspector. To perform well, a penetrant must possess a number of important characteristics. A penetrant must:

- Spread easily over the surface of the material being inspected to provide complete and even coverage.
- Be drawn into surface breaking defects by capillary action.
- Remain in the defect but remove easily from the surface of the part.
- Remain fluid so it can be drawn back to the surface of the part through the drying and developing steps.
- Be highly visible or fluoresce brightly to produce easy to see indications.
- Not be harmful to the material being tested or the inspector.

All penetrant materials do not perform the same and are not designed to perform the same. Penetrant manufactures have developed different formulations to address a variety of inspection applications. Some applications call for the detection of the smallest defects possible and have smooth surfaces where the penetrant is easy to remove. In other applications, the rejectable defect size may be larger and a penetrant formulated to find larger flaws can be used. The penetrants that are used to detect the smallest defect will also produce the largest amount of irrelevant indications. [9] Look the pictures 32



step 1

step 2

step 3

Step 4

Pictures 32 Penetrant testing PT [15]

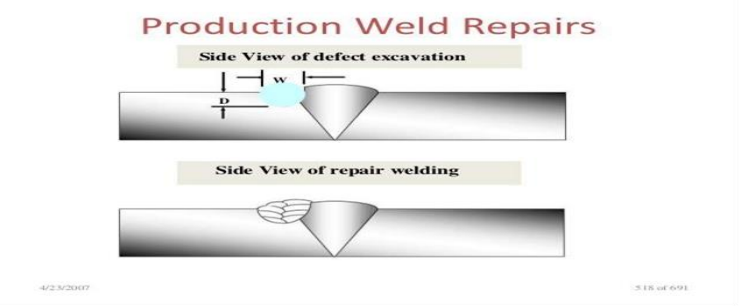
13.6 Welding Repairs:

Welding repairs can divided into two specific areas

- Production repairs
- In- service repairs

13.6.1 Production repairs

The Welding Inspector or NDT operator will usually identify production repair during the process of evaluation of NDT report to the code or applied standard. Look the pictures 33



Picture 33 image of production weld repairs [4]

13.6.2 In service repairs

Most in service repairs can be of very complex nature as the component is very likely to be most in a different position and condition that existed during production. It may also have in contact with toxic or combustible fluid hence a permit to work will need to be sought prior to many work being carried out. The repair welding procedure may look very different to the original production procedure due to changes in these elements.

13.6.3 Weld repair related problems

- heat from welding may affect dimensional stability and/or mechanical properties of repaired assembly
- due to heat from welding, goes down, danger of collapse
- filler materials used on dissimilar weld may lead to galvanic corrosion
- local preheat may induce residual stresses
- cost of weld metal deposited during a weld joint repair can reach up to 10 times the original weld cost

14 Residual Stress and Distortion

Unlike the applied stress, residual stress is induced during processing. There are two kinds of residual stresses which are main concerns.

One is flow induced residual stress. When in molten state, polymer molecules are unstressed, and they tend to equilibrium, random coil state. During processing, the polymer is sheared and elongated, and the molecules are oriented in the flow direction. If solidification occurs before the polymer molecules are fully relaxed to their state of equilibrium, molecular orientation is locked within the moulded part. This kind of stress is often referred to as flow induced residual stress. [9]

Another is thermal induced residual stress which arises during the cooling stage. An important fact is polymer shrinks as it cools. During the cooling stage, the polymer cools at different rates from the mold wall to the centre. When the polymer starts to cool, the external surface layers start to shrink, while the bulk of polymer at the core is still hot and free to contract. Later when the internal core cools, it's contraction is constrained by the external layers since they are already rigid. This leads to another kind of residual stress. Usually the stress distribution is tensile in the core and compressive at the surface.

14.1 Measurement of residual stresses

Unlike the applied stresses, residual stresses cannot be measured directly. On the contrary, they are calculated indirectly by measuring the strains that exist within the material. These strains are generally measured by mechanical or X-ray methods and corresponding stresses calculated from elastic theory formulae.

General techniques to measure residual stresses are:

- Mechanical Residual stress is in a state of self equilibrium before material is removed by mechanical means. After a part of the material is removed, the static equilibrium is upset and stress distribution is altered.
- X-ray

Note that residual stress has effect on the material structure. Our knowledge of the effects of residual stresses on structure can be obtained by X-ray method. For example, to measure the residual stress in metal, X-ray tells of atomic arrangements; deviations from an ideal arrangement can be interpreted as strain; the state of stress can be reconstructed from this strain. [10] Look example in pictures 34

Picture 34 image of Residual stress [15]

15 Distortion

Distortion during welding operation is mainly caused by local heating, cooling and thus local movement of material through local expansion and contraction.

15.1 Distortion being caused

Because welding involves highly localised heating of joint edges to fuse the material, non-uniform stresses are set up in the component because of expansion and contraction of the heated material. Initially, compressive stresses are created in the surrounding cold parent metal when the weld pool is formed due to the thermal expansion of the hot metal (heat affected zone) adjacent to the weld pool. However, tensile stresses occur on cooling when the contraction of the weld metal and the immediate heat affected zone is resisted by the bulk of the cold parent metal.

The magnitude of thermal stresses induced into the material can be seen by the volume change in the weld area on solidification and subsequent cooling to room temperature. For example, when welding CMn steel, the molten weld metal volume will be reduced by approximately 3% on solidification and the volume of the solidified weld metal/heat affected zone (HAZ) will be reduced by a further 7% as its temperature falls from the melting point of steel to room temperature.

If the stresses generated from thermal expansion/contraction exceed the yield strength of the parent metal, localised plastic deformation of the metal occurs. Plastic deformation causes a permanent reduction in the component dimensions and distorts the structure.

15.2 The main types of distortion

Distortion occurs in six main forms:

1. Longitudinal shrinkage
2. Transverse shrinkage
3. Angular distortion
4. Bowing and dishing
5. Buckling
6. Twisting

Non-uniform contraction (through thickness) produces angular distortion in addition to longitudinal and transverse shrinkage.

For example, in a single V butt weld, the first weld run produces longitudinal and transverse shrinkage and rotation. The second run causes the plates to rotate using the first weld deposit as a fulcrum. Hence, balanced welding in a doubleside V butt joint can be used to produce uniform contraction and prevent angular distortion.

Similarly, in a single side fillet weld, non-uniform contraction produces angular distortion of the upstanding leg. Double side fillet welds can therefore be used to control distortion in the upstanding fillet but because the weld is only deposited on one side of the base plate, angular distortion will now be produced in the plate.

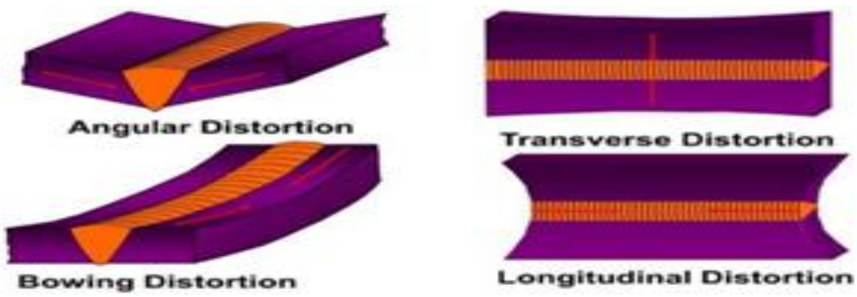
Longitudinal bowing in welded plates happens when the weld centre is not coincident with the neutral axis of the section so that longitudinal shrinkage in the welds bends the section into a curved shape.

Clad plate tends to bow in two directions due to longitudinal and transverse shrinkage of the cladding; this produces a dished shape. Dishing is also produced in stiffened plating. Plates usually dish inwards between the stiffeners, because of angular distortion at the stiffener attachment welds (see main photograph).

In plating, long range compressive stresses can cause elastic buckling in thin plates, resulting in dishing, bowing or rippling.

Distortion due to elastic buckling is unstable: if you attempt to flatten a buckled plate, it will probably 'snap' through and dish out in the opposite direction.

Twisting in a box section is caused by shear deformation at the corner joints. This is caused by unequal longitudinal thermal expansion of the abutting edges. Increasing the number of tack welds to prevent shear deformation often reduces the amount of twisting. [9] Look the pictures 35



Picture 35 image of distortion [15]

16 Heat Treatment

Heat treatment is used to change properties of metal, or as a method of controlling formation of structure, or expansion /contraction forces during welding

The types of Heat Treatment:

16.1 Pre-heating

Pre-heating to an appropriate temperature immediately prior to austenitizing when hardening high hardenability constructional steels, many of the tool steels, and heavy sections.

16.2 Annealing

A term denoting a treatment, consisting of heating to and holding at a suitable temperature, followed by cooling at a suitable rate, used primarily to soften, but also to simultaneously produce desired changes in other properties or in microstructure. The purpose of such changes may be, but is not confined to, improvement of machinability; facilitation of cold working; improvement of mechanical or electrical properties; or increase in stability of dimensions. The time-temperature cycles used vary widely both in maximum temperature attained and in cooling rate employed, depending on the composition of the material, its condition, and the results desired. When applicable, the following more specific process names should be used: Black Annealing, Blue Annealing, Box Annealing, Bright Annealing, Cycle Annealing, Flame Annealing, Full Annealing, Graphitizing, Intermediate Annealing, Isothermal Annealing, Process Annealing, Quench Annealing, and Speroidizing. When the term is used without qualification, full annealing is implied. When applied only for the relief of stress, the process is properly call stress relieving. [6]

16.3 Normalizing

Normalising is a heat treatment process that is generally used for steel. The temperature climb and holding be exactly the same as annealing.

16.4 Quenching hardening

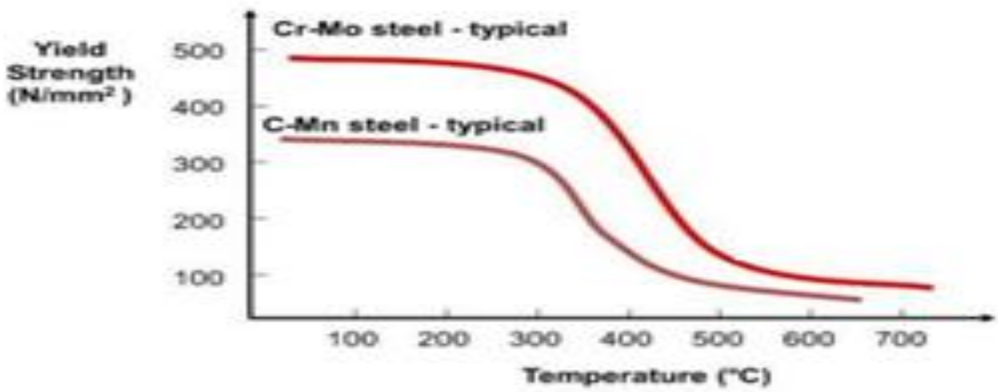
Rapid cooling. When applicable, the following more specific terms should be used: Direct Quenching, Fog Quenching, Hot Quenching, Interrupted Quenching, Selective Quenching, Slack Quenching, Spray Quenching, and Time Quenching.

16.5 Tempering

Heating a quench hardened or normalized ferrous alloy to a temperature below the transformation range to produce desired changes in properties. The object of tempering or drawing is to reduce the brittleness in hardened steel and to remove the internal strains caused by the sudden cooling in the quenching bath. The tempering process consists in heating the steel by various means to a certain temperature and then cooling it. When steel is in a fully hardened condition, its structure consists largely of martensite. On reheating to a temperature of from about 300 to 750°F., a softer and tougher structure known as troostite is formed. If the steel is reheated to a temperature of from 750 to 1290°F, a structure known as a sorbite is formed, which has somewhat less strength than troostite, but much greater ductility?

16.6 Stress reliefs

A process to reduce internal residual stresses in a metal object by heating the object to a suitable temperature and holding for a proper time at that temperature. This treatment may be applied to relieve stresses induced by casting, quenching, normalizing, machining, cold working or welding. [5] Look the pictures 36



Picture 36 weld heat treatment [15]

17 The Weldability of Steel

The weldability of a material to be welded by most of common welding process, and retain the properties for which it has been designed.
The weldibility of steel can involve many factors depending on the type of steel, the process and the mechanical properties required.

17.1 Material types

In terms of weldability, commonly used materials can be divided into the following types:

- Steels
- Stainless steels
- Aluminium and its alloys
- Nickel and its alloys
- Copper and its alloys
- Titanium and its alloys
- Cast iron

Fusion welding processes can be used to weld most alloys of these materials, in a wide range of thickness. When imperfections are formed, they will be located in either the weld metal or the parent material immediately adjacent to the weld, called the heat affected zone (HAZ). As chemical composition of the weld metal determines the risk of imperfections, the choice of filler metal may be crucial not only in achieving adequate mechanical properties and corrosion resistance but also in producing a sound weld. However, HAZ imperfections are caused by the adverse effect of the heat generated during welding and can only be avoided by strict adherence to the welding procedure.

This part of the materials section of Job Knowledge for Welders considers the weldability of carbon- manganese (C-Mn) steels and low alloy steels. [1]

17.2 Imperfections in welds

Commonly used steels are considered to be readily welded. However, these materials can be at risk from the following types of imperfection:

- porosity
- solidification cracking
- hydrogen cracking
- Reheat cracking

Other fabrication imperfections are lamellar tearing and liquation cracking but using modern steels and consumables, these types of defects are less likely to arise.

In discussing the main causes of imperfections, guidance is given on procedure and welder techniques for reducing the risk in arc welding.

17.3 Porosity

Porosity is formed by entrapment of discrete pockets of gas in the solidifying weld pool. The gas may originate from poor gas shielding, surface contaminants such as rust or grease, or insufficient deoxidants in the parent metal (autogenous weld), electrode or filler wire. A particularly severe form of porosity is 'wormholes', caused by gross surface contamination or welding with damp electrodes.

The presence of manganese and silicon in the parent metal, electrode and filler wire is beneficial as they act as deoxidants combining with entrapped air in the weld pool to form slag. Rimming steels with high oxygen content can only be welded satisfactorily with a consumable which adds aluminium to the weld pool.

To obtain sound porosity-free welds, the joint area should be cleaned and degreased before welding. Primer coatings should be removed unless considered suitable for welding by that particular process and procedure. When using gas shielded processes, the material surface demands more rigorous cleaning, such as by degreasing, grinding or machining, followed by final degreasing, and the arc must be protected from draughts.

17.4 Solidification cracking

Solidification cracks occur longitudinally as a result of the weld bead having insufficient strength to withstand the contraction stresses within the weld metal. Sulphur, phosphorus, and carbon pick up from the parent metal at high dilution increase the risk of weld metal (solidification) cracking especially in thick section and highly restrained joints. When welding high carbon and sulphur content steels, then weld beads will be more susceptible to solidification cracking. However, a weld with a large depth to width ratio can also be susceptible. In this case, the centre of the weld, the last part to solidify, will have a high concentration of impurities increasing the risk of cracking.

Solidification cracking is best avoided by careful attention to the choice of consumable, welding parameters and welder technique. To minimise the risk, consumables with low carbon and impurity levels and relatively high manganese and silicon contents are preferred. High current density processes such as submerged-arc and CO_2, are more likely to induce cracking. The welding parameters must produce an adequate depth to width ratio in butt welds, or throat thickness in fillet welds. High welding speeds also increase the risk as the amount of segregation and weld stresses will increase. The welder should ensure that there is a good joint fit-up so as to avoid bridging wide gaps. Surface contaminants, such as cutting oils, should be removed before welding.

17.5 Hydrogen cracking

A characteristic feature of high carbon and low alloy steels is that the HAZ immediately adjacent to the weld hardens on welding with an attendant risk of cold (hydrogen) cracking. Although the risk of cracking is determined by the level of hydrogen produced by the welding process, susceptibility will also depend upon several contributory factors:

- material composition (carbon equivalent);
- section thickness;

- arc energy (heat) input;
- Degree of restraint.

The amount of hydrogen generated is determined by the electrode type and the process. Basic electrodes generate less hydrogen than rutile electrodes (MMA) and the gas shielded processes (MIG and TIG) produce only a small amount of hydrogen in the weld pool. Steel composition and cooling rate determines the HAZ hardness. Chemical composition determines material hardenability, and the higher the carbon and alloy content of the material, the greater the HAZ hardness. Section thickness and arc energy influences the cooling rate and hence, the hardness of the HAZ.

For a given situation therefore, material composition, thickness, joint type, electrode composition and arc energy input, HAZ cracking is prevented by heating the material. Using preheat which reduces the cooling rate, promotes escape of hydrogen and reduces HAZ hardness so preventing a crack-sensitive structure being formed; the recommended levels of preheat for various practical situations are detailed in the appropriate standards e.g. BS EN1011-2:2001. As cracking only occurs at temperatures slightly above ambient, maintaining the temperature of the weld area above the recommended level during fabrication is especially important. If the material is allowed to cool too quickly, cracking can occur up to several hours after welding, often termed 'delayed hydrogen cracking'. After welding, therefore, it is beneficial to maintain the heating for a given period (hold time), depending on the steel thickness, to enable the hydrogen to diffuse from the weld area.

When welding C-Mn structural and pressure vessel steels, the measures which are taken to prevent HAZ cracking will also be adequate to avoid hydrogen cracking in the weld metal. However, with increasing alloying of the weld metal e.g. when welding alloyed or quenched and tempered steels, more stringent precautions may be necessary.

The risk of HAZ cracking is reduced by using a low hydrogen process, low hydrogen electrodes and high arc energy, and by reducing the level of restraint. Practical precautions to avoid hydrogen cracking include drying the electrodes and cleaning the joint faces. When using a gas shielded process, a significant amount of hydrogen can be generated from contaminants on the surface of the components and filler wire so preheat and arc energy requirements should be maintained even for tack welds.

17.6 Reheat cracking

Reheat or stress relaxation cracking may occur in the HAZ of thick section components, usually of greater than 50mm thickness, Fig. 4. The more likely cause of cracking is embrittlement of the HAZ during high temperature service or stress relief heat treatment.

As a coarse grained HAZ is more susceptible to cracking, low arc energy input welding procedures reduce the risk. Although reheat cracking occurs in sensitive materials, avoidance of high stresses during welding and elimination of local points of stress concentration, e.g. by dressing the weld toes, can reduce the risk. [9]

17.7 Weldability of steel groups

PD CEN ISO/TR 15608:2005 identifies a number of steels groups which have similar metallurgical and welding characteristics. The main risks in welding these groups are:

Low carbon unalloyed steels, no specific processing requirements, specified minimum yield strength R eH ≤ 460N/mm 2.

For thin section, unalloyed materials, these are normally readily weldable. However, when welding thicker sections with a flux process, there is a risk of HAZ hydrogen cracking, which will need increased hydrogen control of the consumables or the use of preheat.

18 The Practice of Visual Inspection

When I was in AEL school studying IWS course I got from their an important information that how well the practice weld visual inspection is so easy to succeed? The response was that ease and know-how are often inversely proportional as following:

- If the basic information is weak, inspection seems easy, but with the inspection we will get a little information to find out, and also inspection is more or less unreliable.

- If the basic information is good, inspection is difficult, but with the inspection we can get more information, experience and inspection is more trusty.

- An experienced inspector can see the same weld a lot more than the inexperienced.

- Visual inspector is limited to the surface, so consequently, can only detect defects on the work piece opening. But a trained inspector can decide also weld profile, his height of the convex weld, weld frankness etc. and it is also more defect such as lack of fusion or incomplete root penetration existence.

Wilts MI and UI are often undertaken by external specialist inspector, visual inspection VI is always undertaken, at least in part; by the manufacturing own personnel hence the inclusion of more detailed guidance on visual inspection on this guide. In practice, although visual inspection is just one of the NDE disciplines, for many structural steelworks it may be one the only form of the NDE required.

Guidance and basic requirement for visual is given in BS EN ISO 17637 Non Destructive Testing of weld – Visual testing of fusion-welded joints.

BS EN ISO 17637 outlines following information:

- Requirement for welding inspection personnel
- Recommendations about condition suitable for visual examination.
- The use of gouges/ inspection aids that may be needed and helpful for inspection.
- Guidance about when inspection may be required during the stages of fabrication.
- Guidance about information that may need to be included in the inspection records. [4]

18.1 Welding inspection personnel

Before starting work on a particular contract BS EN 17637 states that the welding inspectors should:

- Be familiar with relevant standards, rules and specification of fabrication work that be is to be undertaken.
- Standards may be national or client.
- Be informed about the welding procedures to be used.
- Have good vision- in accordance with EN 473 and should be checked every 12 months.

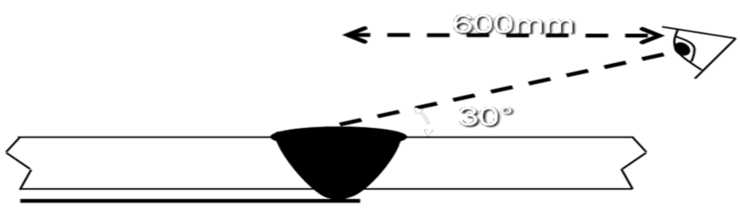
18.2 Condition for visual inspection And Illumination

BS EN 17637 states that the minimum illumination shall be 350 lux but recommends a minimum of 500 lux (normal shop or office lighting).

18.3 Access

Access to the surface, for direct inspection, should enable the eyes:

- To within 600 mm of the surface being inspected. As shown in picture 37
- To be in a position to give a viewing angle of not less than 30 degree.



Picture 37 visual test distance [15]

18.4 Aids to visual inspection

Where access is restricted for direct visual inspection, the use of a mirrored bo-rescope, or a fibre optic viewing system, are options that may be used- usually by agreement the contacting parties.

It may also be necessary to provide auxiliary lighting (such as torch) to give suitable contrast and relief between surface imperfections and the background.

Other terms of equipment that may be appropriate to facilitate visual examination are:

- Welding gauges- for checking bevel angles and weld profile, fillet sizing, measuring undercut depth.
- Dedicated weld gap-gauges and linear misalignment (high-low) gauges
- Straight edges and measuring tapes
- Magnifying lens-if magnification lens used to aid visual examination it should be x2 to x5 magnifications.

18.5 Visual Inspection Duties

Visual inspection of the finished weld is a minimum requirement. For fabricated items that must have high integrity, such as larges structure, inspection will usually be required throughout the fabrication process, namely:

- Before welding
- After welding
- During welding

18.6 Typical duties of welding inspectors

Visual inspection of the finished weld is a minimum requirement. For fabricated items that must have high integrity, such as larges structure, inspection will usually be required throughout the fabrication process, namely:

- Before welding
- After welding
- During welding

The relevant standards, rules and specification that a welding inspectors should be familiar with at the start of contract areal the documents required for reference during the fabrication sequence in order to make judgements about particular details:

- The application standards for visual acceptance criteria
- Quality plan or inspection check lists
- Drawings
- Quality procedures

A typical list of welding Inspectors duties may be produced which for simplicity can be initially grouped into three specific areas:

18.7 Before welding

18.7.1 Safety

Ensure that all operations are carried out in complete compliance with local, company, or national safety legislation (i.e. permits to work are in place).

18.7.2 Documentation

- Check specification
- Check drawings
- Check WPS (Welding procedure and specification) and Welding approvals

- Validate certificate of calibration. (welding equipment &inspection instruments)
- Check material and consumable certification

18.7.3 Welding Process and ancillaries:

Check welding equipment and all related ancillaries.(Cables, regulator, ovens, quivers etc.)

18.7.4 Incoming consumables:

To check pipe/plat and welding consumables for size, condition, specification and storage.

18.7.5 Marking out preparation &set up:

Check the:

- Correct method for cutting weld preparation. (pre-heat for thermal cutting if applicable)
- Correct preparation (relevant bevel angles, root face, root gap, root radius, land, etc)
- Correct pre-welding distortion control. (Tacking, Bridging, jigs, line up clamps, etc)
- Correct level and method of pre-heat applied to tack welding
- All tack welding to be monitored and inspected. (Feathering of task may be required) [10]

- Weather condition.
- Pre-heat values.
- In process distortion control and consumable control.

- Welding process and all related variable parameters. (voltage, amperage, travel speed, etc)

- Welding or purging gases.

- Welding condition for root run / hot pass and all subsequent run, and inter-run cleaning)

- Minimum or maximum inter pass temperatures.

18.8 After welding:

- Carry out visual inspection of the welding joint.

- Check and monitor NDT requirements.

- Identify repairs from assessment of visual or NDT report.

- Post weld heat treatment PWHT (Heating method and temperature recording system)

- Re-inspect with NDE/NDT after PWHT. (IF applicable)

- Hydrostatic test procedures. (For pipeline or pressure vessels) [10]

18.8.1 Repairs:

- Excavation procedure. (approval and execution)

- Approval of the NDT procedures (For assessment of complete defect removal)
- Execution of approval re-welding procedures.

- Re-inspect the repair areas with visual inspection and approval NDT method

To be effective, a Welding Inspector requires a high level of knowledge, experience and a good understanding of the job. This should in turn earn some respect from the welder.

Good Welding Inspectors should carry out their duties competently, use our authority wisely and be constantly aware of their responsibilities.

19 Visual welding inspection practical forms

The requirement for examination record / inspection reports will vary according to contract and type of fabrication and there may not always be need for a formal record.

20 The Standard EN ISO 1090

20.1 EN 1090-2 Welding

Welding shall be undertaken in accordance with the requirements of the relevant part of EN ISO 3834 or EN ISO 14554 as applicable. NOTE Guidelines for implementation of EN ISO 3834 on quality requirements for fusion welding of metallic materials is given in CEN 3834-6. [13]

According to the execution class, the following parts of EN ISO 3834 apply:

EXC1: Part 4 "Elementary quality requirements";

EXC2: Part 3 "Standard quality requirements";

EXC3 and EXC4: Part 2 "Comprehensive quality requirements".

20.2 EN 1090-2 Welders and welding operators

Welders shall be qualified in accordance with EN 287-1 and welding operators in accordance with EN 1418.Welders of hollow section branch connection with angles less than 60° as defined in EN 1993-1-8 shall be qualified by specific test.

Records of all welder and welding operator qualification tests shall be kept available. Tack welds For EXC2, ECX3 and EXC4, tack welds shall be made using a qualified welding procedure. The minimum Length of the tack shall be the lesser of four times the thickness of the thicker part or 50 mm, unless a shorter Length can be demonstrated as satisfactory by test.

All tack welds not incorporated into the final welds shall be removed. Tack welds that are to be incorporated into the final weld shall have a suitable shape and be carried out by qualified welders. Tack welds shall be free from deposition faults and shall be cleaned thoroughly before final welding. Cracked tack welds shall be removed.

20.3 EN 1090-2 Welding Coordination

20.3.1 Welding coordination

For EXC2, EXC3 and EXC4, welding coordination shall be maintained during the execution of welding by welding coordination personnel suitably qualified for, and experienced in the welding operations they supervise as specified in EN ISO 14731.

20.4 EN 1090-2 Welding – WPS

Qualification of welding procedures for processes 111, 114, 12, 13 and 14

a) The qualification of the welding procedure depends on the execution class, the parent metal and the degree of mechanization.

b) If EN ISO 15613 or EN ISO 15614-1 qualification procedures are used, the following conditions apply:

1) If impact tests are specified, they shall be carried out at the lowest temperature required for impact testing of the material qualities being joined.

2) For steels according to EN 10025-6, one specimen for micro-examination is necessary. Photographs of weld metal, fusion line zone and HAZ shall be recorded. Micro cracks are not permitted.

3) If welding on shop primers, tests shall be carried out on the maximum (nominal + tolerance) accepted layer thickness.

c) If a qualification procedure is to apply to transverse stressed fillet welds on steel grades higher than S275, test shall be completed by a cruciform tensile test performed in accordance with EN ISO 9018. Only specimens with a ≤0.5 *t* shall be evaluated. Three cross tensile specimen shall be tested. If the fracture happens in the parent metal, the minimum nominal tensile strength of the parent metal shall be reached. If the fracture happens in the weld metal, the fracture strength of the cross Section of the actual weld shall be determined. By processes with deep penetration the actual root penetration shall be considered. The determined average fracture strength shall be ≥ 0,8 Rm (with *R* nominal tensile strength of the used parent metal).

20.5 EN 1090·2Welding - WPS Qualification

20.5.1 Validity of a welding procedure qualification

The validity of a welding procedure depends on the requirements of the standard used for the qualification. If specified, welding production tests have to be carried out in accordance with the relevant standard of qualification, e.g. EN ISO 14555.
The following additional tests are required for a welding procedure qualified in accordance with EN ISO 15614-1 which is undertaken by a welding process that has not been used:

a) For a period of between one and three years, a suitable production welding test shall be carried out for steel grades higher than 5355. Examination and testing shall include visual inspection, radiographic or ultrasonic inspection (not required for fillet welds), surface crack detection by magnetic particle or penetrant test, macro-examination and hardness test;
b) For a period of more than three years,

1) A macro specimen taken from a production test shall be inspected for acceptability for steel grades up to and including 5355, or

2) New welding procedure tests shall be carried out for steel grades higher than 5355 as relevant.
For resistance welding, the welding parameters may be determined using tests according to EN ISO 10447. [13]

Summary

EU directives require products and structures with safety. Since welding is often the most critical step, EN Standards are the technical and personnel requirments to minimize the risks. Pressure Equipment Directive and manufacturing standards and the future nuclear power plant is the most demanding welding. Welding inspection are also the most pressing challenges of Finnish technical researcher. Also, the construction industry is waking up to the requirements, and will also be there on the side of much tougher.

The standard SFS-EN ISO 3834 is shown in welded structures of companies manufacturing rules of the game. The standard provides the basis on which products can be manufactured with high quality. The manufacturer will also be available in sufficient coordination staff, the company to be designated. Welding inspector requirements should be set to firm behaviour / activity. The importance of welding inspection is particularly pronounced in modern commerce, when technical researcher is increasingly outside Finland, and their numbers are still growing!

Welding coordination tasks include following terms:

- Negotiation audits of inspection and welding production methods
- Method of testing and monitoring of the WPS contract Bs
- Internal and independent audits and monitoring of the audit sub-contractors
- Welding production development and maintenance
- Knowledge of welding standards in the industry and know-how to apply them to the production
- Participation in the trading of foreign subcontractors
- Welding equipment and bulwarks of acquisition, maintenance and repair activities responsibility
- The latest DT and NDT standards of knowledge and expertise in the interpretation is responsible for ensuring that the products are order specification with the material, as well as the monitoring of activities

References:

[1] Foundation, Concrete and Earthquake Engineering (www.civil-enggworld.blogspot.com)

[2] The Esab group welding subsidiary company (www.esab.fi)

[3] The NDT Resource Center

[4] Welder Training Organizations (www.cswip.com)

[5] Industrial Ovens - Wisconsin Oven (www.wiscoven.com)

[6] Advanced Composites Manufacturing Centre (wwwTech.plym.ac.uk)

[7] 2010 mechanical engineering Blogger Template By Blogger Theme (Engi nearing hut.blogs.com)

[8] RoyMech Mechanical engineering (www.roymech.co.uk)

[9] The world's largest community for sharing presentations and other professional content. (www.slideshare.net)

[10] Training & Examination Service Worldwide (www.twi.com)

[11] AEL School Machinery And Metal Product Department (www.ael.fi)

[12] Material Testing laboratory Engineering Service (www.tcreng.com)

[13] Execution of Steel Structure of standards EN ISO 1090

[14] **(**Stefano Morra IIS CERT – Italian Institute of Welding Group)

[15] Images of welding pictures (Google)