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JOINING OF CAST IRON BY USING SHIELDED METAL ARC WELDING (SMAW): A Review.

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Abstract : Shielded metal arc welding (SMAW) process is one of the most commonly employed material joining processes utilized in the various industrial sectors such as marine, ship-building, automotive, aerospace, construction and petrochemicals etc. The increasing pressure on manufacturing sector wants the welding process to be sustainable in nature. The SMAW process incorporates several types of inputs and output streams. The sustainability concerns associated with SMAW process are linked with the various input and output streams such as electrical energy requirement, input material consumptions, slag formation, fumes emission and hazardous working conditions associated with the human health and occupational safety. To enhance the environmental performance of the SMAW welding process, there is a need to characterize the sustainability for the SMAW process under the broad framework of sustainability. Most of the available literature focuses on the technical and economic aspects of the welding process, however the environmental and social aspects are rarely addressed. The study reviews SMAW process with respect to the triple bottom line (economic, environmental and social) sustainability approach. Finally, the study concluded recommendations towards achieving economical and sustainable SMAW welding process.

INTRODUCTION

Shielded metal arc welding (SMAW), also known as manual metal arc welding (MMA or MMAW), flux shielded arc weldingor informally as stick welding, is a manual arc welding process that uses a consumable electrode covered with a flux to lay the weld.An electric current, in the form of either alternating current or direct current from a welding power supply, is used to form an electric arc between the electrode and the metals to be joined. The workpiece and the electrode melts forming a pool of molten metal (weld pool) that cools to form a joint. As the weld is laid, the flux coating of the electrode disintegrates, giving off vapors that serve as a shielding gas and providing a layer of slag, both of which protect the weld area from atmospheric contamination.

Because of the versatility of the process and the simplicity of its equipment and operation, shielded metal arc welding is one of the world's first and most popular welding processes. It dominates other welding processes in the maintenance and repair industry, and though flux-cored arc welding is growing in popularity, SMAW continues to be used extensively in the construction of heavy steel structures and in industrial fabrication. The process is used primarily to weld iron and steels (including stainless steel) but aluminium, nickel and copper alloys can also be welded with this method.

SMAW process and equipment.

Process:SMAW uses the heat of the arc to help melt the top of a consumable covered electrode and base metal. Both the electrode and item being welded are a part of an electric circuit. This circuit also includes the power source, welding cables, electrode holder and ground clamp.The cables from the power source are attached to the work and electrode holder. Welding begins when an arc forms between the base metal and tip of the electrode. The surface of the work and electrode tip are melted.Metal then forms on the end of the electrode, transferring from the arc into a pool. Filler is deposited when the electrode is consumed. The arc in SMAW nogets extremely hot — temperatures can exceed 9,000 degrees Fahrenheit!

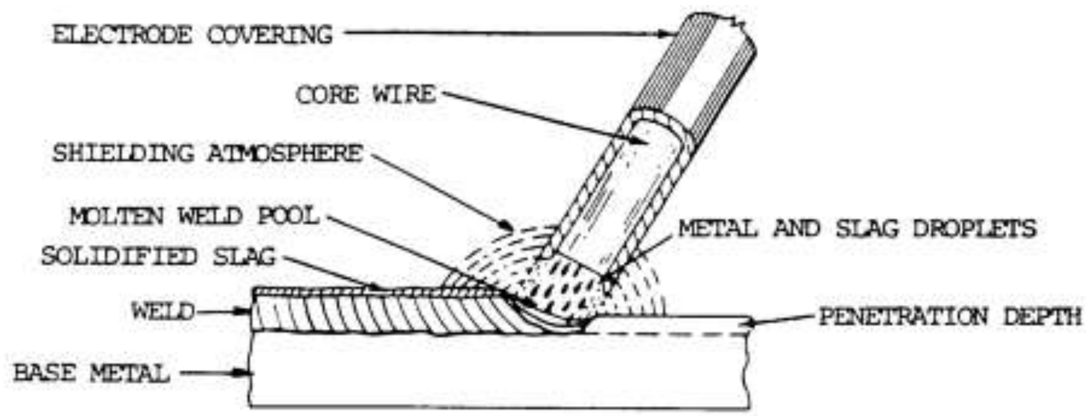

fig: shielded metal arc welding (SMAW)

Equipment: The equipment needed for shielded metal arc welding is much less complex than that needed for other arc welding processes. Manual welding equipment includes a power source (transformer, dc generator, or dc rectifier), electrode holder, cables, connectors, chipping hammer, wire brush, and electrodes.

(2) The shielded metal arc welding process requires sufficient electric current to melt both the electrode and a proper amount of base metal, and an appropriate gap between the tip of the electrode and base metal or molten weld pool. These requirements are necessary for coalescence. The sizes and types of electrodes for shielded metal arc welding define the arc voltage requirements (within the overall range of 16 to 40 V) and the amperage requirements (within the overall range of 20 to 550 A). The current may be either alternating or direct, but the power source must be able to control the current level in order to respond to the complex variables of the welding.

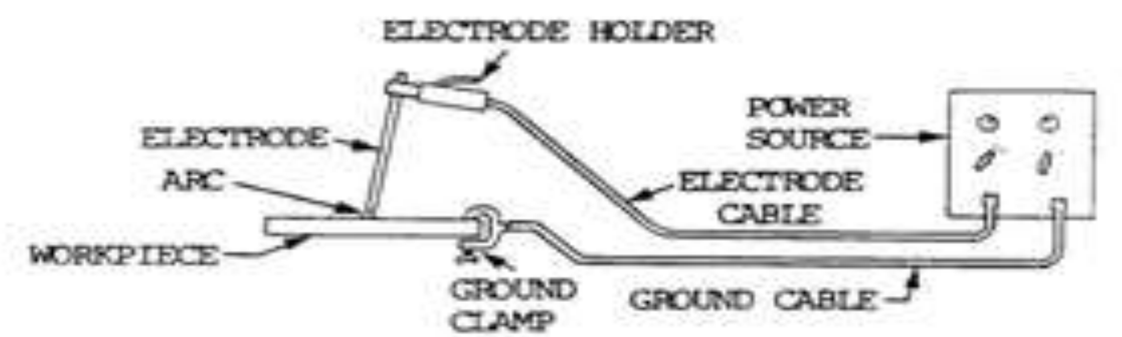

fig: SMAW equipment

STUDY AND FINDINGS

Ch.Indira Priyadarsini et. al. [1] the main issue or main difficulties in the large industries are, the residual stress and overall distortion has been formulated. The main aim of this topic is reduce the residual stress and distortion effect. For experimental study of this thesis SAW has been chosen, thermal effect of submerged arc are depend on the electric arc flux and temperature of work piece material . The SAW is simulated by FEM and ANSYS for the optimization of process parameter material temperature decreased and distance of center point increased

J.O Olawale et.al [2] these investigations are established the correlation of SMAW and heat treatment on some mechanical properties of carbon steel. The sample is weld together by using AWS E6013electrode .during welding voltage are constant and current are varying, correlate voltage and current. The sample is

subjected to heat treatment operation at different temperature. As it is found that with increase in current increase in hardness and UTS of weld metal .after heat treatment operation impact strength increase while UTS and hardness reduced.

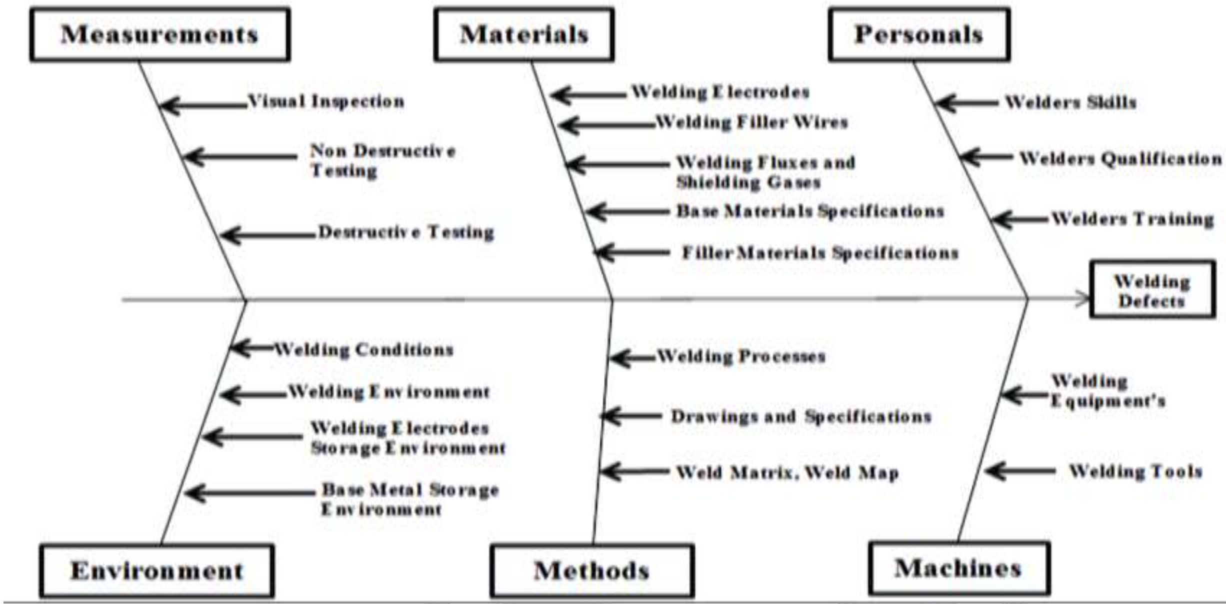

fig: SMAW cause and defect Diagram of welding defects.

B.S Praveen kumar et.al [3] the present work of this paper during SMAW process the design parameter are perform experimentally to insure leak profile joint. The SMAW welding parameter are current, voltage, welding speed , electrode angle these parameter are calculated by ANOVA and experimentally result are conducted according to orthogonal array.

Maridurai T et.al [4] to investigate that the tensile properties of carbon steel P91 when root pass was carried by using TIG welding and then SMAW and SAW welding to be perform .the study of characteristics of fracture , toughness and tensile properties of P91 material in SAW process. The fracture, toughness and tensile properties of base metal are evaluated by using crack tip opening displacement and properties are measure at room temperature, the range of temperature during welding is 400-600 degree centigrade.

Dae-Won Cho et. al. [5] the main area of this single wire submerged arc welding is the effect of heat transfer and torch angle current density are to analyzed .In this paper CFD numerical model are used in single electrode SAW process. To develop the arc model such as electromagnetic force, arc heat flux is adopting able inversion method with CFD compare for DC and AC polarities. The CFD numerical method is used to comparison of experimental result

Harmeet singh et. al. [6] In this paper work transient temperature and residual stress are evaluated when two dissimilar metal are joint by SMAW process due to presence of residual stress ,life of joint will be decrease for evaluate the residual stress and transient temperature can be evaluated by using FEM and ANSYS software during welding process . Tensile stress is occurring inside the cylinder, peak circumferential stress is outside the cylinder. The residual stress is influenced by the inside and outside weld FE

J Dutta et.al. [7] This paper deals with the variation of temperature in heat effect zone in weld joint these properties depend on material properties. Temperature are measure by experimental at predefined location of the plate during welding by mounting of thermocouple. The heat transfer in heat effect zone are carried out convection, radiation and radiation heat transfer are main role of heat losses due to moving plate heat source. The variation of temperature in heat effect zone is 300°c to 600°c.

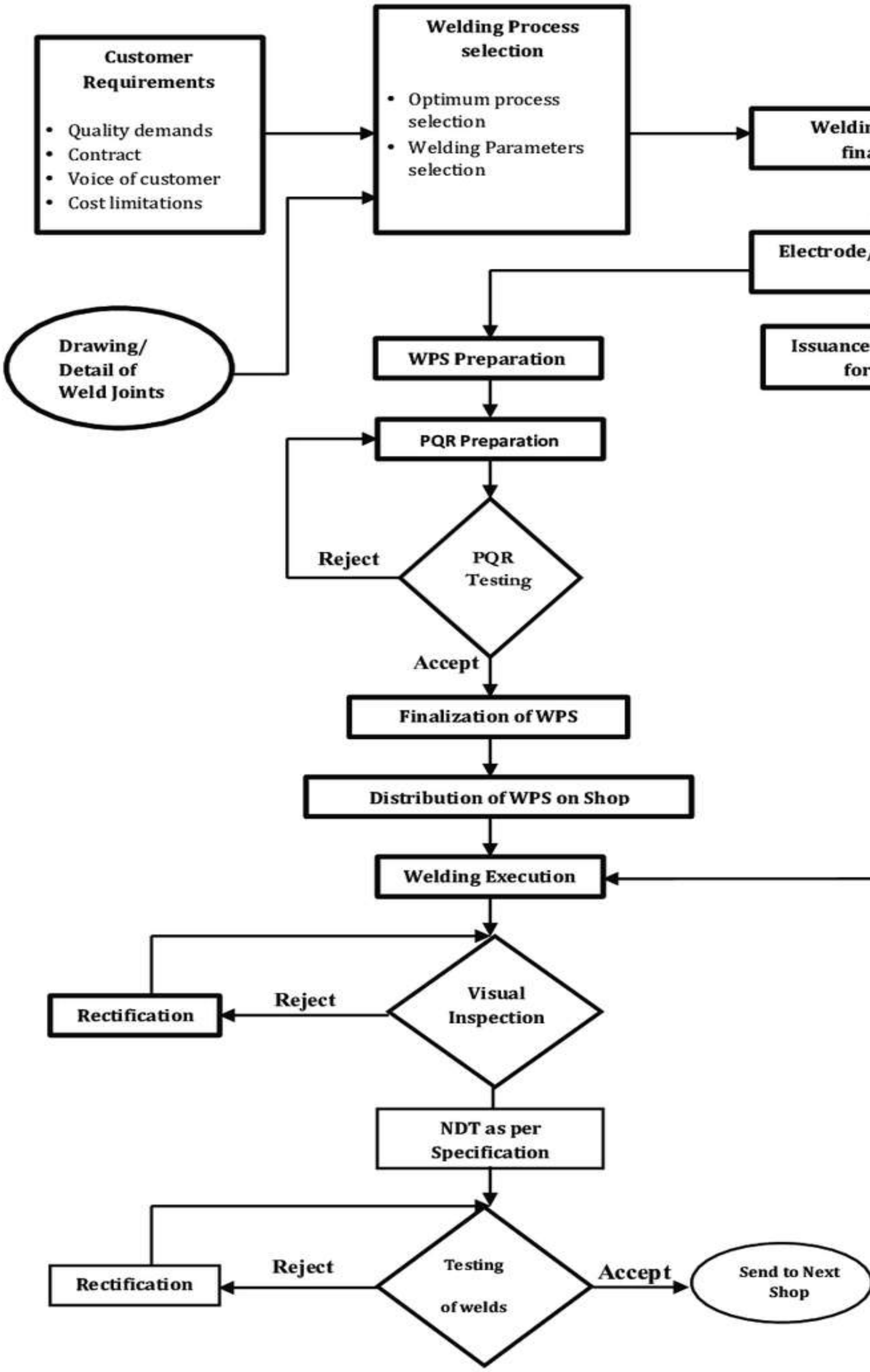

fig : flow chart work piece properties

Rohit jha et.al [8] to study the welding characteristic of different types of weld design and weld metal, the types joint design are v, flat surface to joint by SMAW welding process , varying welding current in all cases. Evaluate all mechanical properties like as % of elongation, tensile strength, yield strength of weld metal and it also show the effect of current on welding speed, yield strength experimentally .the UTS and YS are maximum in V joint design and it conclude that before and at optimum value of UTS, current increase, UTS also increase after optimum value of UTS current increase UTS decrease.

Osman culha et.al [9] this paper are focused on to predict the design parameter like as distortion analysis, thermal stress, temperature gradient, nodal displacement on the plate during saw process. The residual stress and distortion are occurring near the HAZ by heating during welding process. The design parameter value is achieved by the analysis of thermal elastic plastic by using FEA .It also show stress- temperature distribution. During SAW process T-beam profile are used in welding.

Rohit jha et.al [10] to investigate the effect welding parameter ,welding current ,voltage ,heat input on UTS of mild steel in SMAW process and evaluate the optimum welding current . the UTS of weld metal are to be investigated by using tensile testing machine , the welding current are varying and at 120am the tensile strength of weld metal are high and after optimum value current increase ,UTS decrease.

AWS SPECIFICATION	E6013
Tensile strength	470 mpa
Yield strength	410 mpa
Elongation.	28 %

Table: mechanical properties of electrodes used .

Y. kchaou et. al. [11] in this paper work measures the mechanical properties and microstructure of base metal of welded joint. The SMAW was performing on joining two stainless steel plates. The measurement of mechanical properties and analysis of fracture profile are show that these two materials are ductile but ductility is less in the weld metal. The hardness of base metal is indicated as micro hardness measurement as the hardness Increases in the weld bead due to rapid cooling of weld material. In ductile material the fracture surface are observed after tensile test of material .All the test of mechanical properties such as micro hardness ,yield strength, tensile strength are in good agreement.

Swapnil R. Deogade et. al. [12] the main purpose of this paper work are thermal analysis it show temperature and residual stress distribution on welded plate. The analysis of residual stress in heat effect zone and welded zone are carried out. The temperature and residual stress are to be simulated by ANSYS. This paper deals the SMAW welding in ferrite stainless steel by using of FEA. In 3-d finite element model the predicted value of temperature and residual stress distribution are obtain.FEA analysis of residual stress are carried out ANSYS.

SMAW input parameter.

Shielded Metal Arc Welding (SMAW) is one of the most important welding process used in the industry for joining ferrous and nonferrous metals. In an arc welding process random variations in current and voltage takes place. Reliable acquisition of these variations during actual welding process and its subsequent analysis can be very useful to various parameters of the arc welding process. Now a day, the welding power sources have a provision of advance arc control to suitably adjust the welding parameters with minimum time delay and to set the right welding parameters during actual process. Hence, to study the exact behaviour of these modern power sources used for welding it is essential to acquire all the possible minute variations taking place while welding is in progress. In the present study, the effect of varying input current and welding power sources on SMAW process is studied. To evaluate the effect of current variations in a SMAW process data were acquired at different current values (from 70 to 120 A). Similarly, to study the behaviour of welding power sources data acquisition was done for six different welding power sources. In both the cases data were acquired at a sampling rate of 100,000 samples/s for duration of 20 s using a general purpose DSO while welding is in progress. These welds were prepared using same type of welding electrode by the same welder employing the identical parameters. The data thus obtained was filtered using the Fast Fourier Transform (FFT) low pass filter and subjected to statistical and neural network analyses. From the Probability Density Distributions (PDDs) and Self Organized Maps (SOM) generated using the data acquired, it is possible to differentiate various weld geometry. Further using these analyses, it is also possible to evaluate the performances of the different welding power sources. Grading of the power sources based on SOM technique matched well with grading arrived at based on the appearance of the weld bead. Results clearly indicate that the procedure presented here can be effectively used to assess the various parameters of welding power sources.

Electrode detail:

An electrode is a metal wire that is coated.It is made out of materials with a similar composition to the metal being welded.There are a variety of factors that go into choosing the right electrode for each project. In summary:SMAW or stick electrodes are consumable, meaning they become part of the weld and are also referred to as a filler electrode or welding rod.TIG tungsten electrodes are non-consumable as they do not melt and become part of the weld, requiring the use of a welding rod.TIG filler rods are an optional filler material used to fuse two pieces of stock together as a composite.The MIG welding electrode is a continuously fed wire referred to as MIG wire.An electrode is a metal wire that is coated.It is made out of materials with a similar composition to the metal being welded.There are a variety of factors that go into choosing the right electrode for each project. In summary:SMAW or stick electrodes are consumable, meaning they become part of the weld and are also referred to as a filler electrode or welding rod.TIG tungsten electrodes are non-consumable as they do not melt and become part of the weld, requiring the use of a welding rod.TIG filler rods are an optional filler material used to fuse two pieces of stock together as a composite.The MIG welding electrode is a continuously fed wire referred to as MIG wire.

Classification

The welding industry has adopted the American Welding Society's classification number series for weldingelectrodes.The electrode identification system for steel arc welding is set up as follows:E – indicates electrode for arc welding.The first two (or three) digits – indicate tensile strength (the resistance of the material to forces trying to pull it apart) in thousands of pounds per square inch of the deposited metal.The third (or fourth) digit – indicates the position of the weld. 0 indicates the classification is not used; 1 is for all positions; 2 is for flat and horizontal positions only; 3 is for flat position only.The fourth (or fifth) digit – indicates the type of electrode coating and the type of power supply used; alternating or direct current, straight or reverse polarity.The types of coating, welding current, and polarity position designated by the fourth (or fifth) identifying digit of the electrode classification are listed in Tables 5-4 below.The number E6010 – indicates an arc welding electrode with minimum stress relieved tensile strength of 60,000 psi; is used in all positions, and reverse polarity direct current is required.

Testing of metal:

Distribution: Weld material is distributed equally between the two material that joind .

Waste: The weld is free of waste materials such as slag. The slag after cooling should peel away from the project. It should be removed easily. In Mig welding, any residue from the shielding gas should also be removed with little problem. TIG, being the cleanest process, should also be waste-free. In Tig, if you see waste, it usually means that the material being welded was not cleaned thoroughly.

- Porosity: The weld surface should not have any irregularities or any porous holes (called porosity). Holes contribute to weakness. If you see holes it usually indicates that the base metal was dirty or had an oxide coating. If you are using Mig or Tig, porosity indicates that more shielding gas is needed when welding. Porosity in aluminum welds is a key indicator of not using enough gas.
- Tightness: If the joint is not tight, this indicates a weld problem. In oxyacetylene welding, if using autogenous welding, where there is no filler material, the weld must be tight. Same for Tig autogenous welding. The gap is not as critical in other types of welds since any gap is filled in by the filler material. That said, gaps, in general, indicate a potential quality problem.
- Leak-Proof: If you are repairing an item that contains liquid, a leak is a sure-fire way (and obvious way) to see that there is a problem. Same for something that will contain a gas. One testing method is to use soap bubbles to check for problems (can be easily applied with a squirt bottle.
- Strength: Most welds need to demonstrate the required strength. One way to ensure proper strength is to start with a filler metal and electrode rating that is higher than your strength requirement.

Destructive testing:

destructive testing (or destructive physical analysis, DPA) tests are carried out to the specimen's failure, in order to understand a specimen's performance or material behavior under different loads. These tests are generally much easier to carry out, yield more information, and are easier to interpret than nondestructive testing. Destructive testing is most suitable, and economic, for objects which will be mass-produced, as the cost of destroying a small number of specimens is negligible. It is usually not economical to do destructive testing where only one or very few items are to be produced (for example, in the case of a building). Analyzing and documenting the destructive failure mode is often accomplished using a high-speed camera recording continuously (movie-loop) until the failure is detected. Detecting the failure can be accomplished using a sound detector or stress gauge which produces a signal to trigger the high-speed camera. These high-speed cameras have advanced recording modes to capture almost any type of destructive failure.[1] After the failure the high-speed camera will stop recording. The captured images can be played back in slow motion showing precisely what happens before, during and after the destructive event, image by image.

Tensile testing
A tensile test, also known as a tension test, is one of the most fundamental and common types of mechanical testing. A tensile test applies tensile (pulling) force to a material and measures the specimen's response to the stress. By doing this, tensile tests determine how strong a material is and how much it can elongate. Tensile tests are typically conducted on electromechanical or universal testing machines, are simple to perform, and are fully standardlized.

Hardness testing.
hardness test is typically performed by pressing a specifically dimensioned and loaded object (indenter) into the surface of the material you are testing. The hardness is determined by measuring the depth of indenter penetration or by measuring the size of the impression left by an indenter.

Spectro testing
The principle of the analysis method of SPECTRO´s portable and mobile metal analyzers is optical emission spectroscopy (arc spark OES or spark OES). Sample material is vaporized with the testing probe by an arc spark discharge. The atoms and ions contained in the atomic vapor are excited into emission of radiation.

Microstructrue testing
Microstructural examination is generally performed using optical or scanning electron microscopes to magnify features of the material under analysis. The amount or size of these features can be measured and quantified, and compared to acceptance criteria.

Non Destructive testing:

Nondestructive testing (NDT) is any of a wide group of analysis techniques used in science and technology industry to evaluate the properties of a material, component or system without causing damage. The terms nondestructive examination (NDE), nondestructive inspection (NDI), and nondestructive evaluation (NDE) are also commonly used to describe this technology.Because NDT does not permanently alter the article being inspected, it is a highly valuable technique unithat can save both money and time in product evaluation, troubleshooting, and research. The six most frequently used NDT methods are eddy-current, magnetic-particle, liquid penetrant, radiographic, ultrasonic, and visual testing. NDT is commonly used in forensic engineering, mechanical engineering, petroleum engineering, electrical engineering, civil engineering, systems engineering, aeronautical engineering, medicine, and art. in the field of nondestructive testing have had a profound impact on medical imaging, including on echocardiography, medical ultrasonography, and digital radiography.

NDT methods rely upon use of electromagnetic radiation, sound and other signal conversions to examine a wide variety of articles (metallic and non-metallic, food-product, artifacts and antiquities, infrastructure) for integrity, composition, or condition with no alteration of the article undergoing examination. Visual inspection (VT), the most commonly applied NDT method, is quite often enhanced by the use of magnification, bores copes, cameras, or other optical arrangements for direct or remote viewing. The internal structure of a sample can be examined for a volumetric inspection with penetrating radiation (RT), such as X-rays, neutrons or gamma radiation. Sound waves are utilized in the case of ultrasonic testing (UT), another volumetric NDT method – the mechanical signal (sound) being reflected by conditions in the test article and evaluated for amplitude and distance from the search unit (transducer). Another commonly used NDT method used on ferrous materials involves the application of fine iron particles (either suspended in liquid or dry powder – fluorescent or colored) that are applied to a part while it is magnetized, either continually or residually. The particles will be attracted to leakage fields of magnetism on or in the test object, and form indications (particle collection) on the object's surface, which are evaluated visually. Contrast and probability of detection for a visual examination by the unaided eye is often enhanced by using liquids to penetrate the test article surface, allowing for visualization of flaws or other surface conditions. This method (liquid penetrant testing) (PT) involves using dyes, fluorescent or colored (typically red), suspended in fluids and is used for non-magnetic materials, usually metals.

CPT Testing

The cone penetration or cone penetrometer test is a method used to determine the geotechnical engineering properties of soils and delineating soil stratigraphy. It was initially developed in the 1950s at the Dutch Laboratory for Soil Mechanics in Delft to investigate soft soils.

MPI Testing

Magnetic particle Inspection is a non-destructive testing process for detecting surface and shallow subsurface discontinuities in ferromagnetic materials such as iron, nickel, cobalt, and some of their alloys.

Ultrasonic Testing

Ultrasonic testing (UT) is a family of non-destructive testing techniques based on the propagation of ultrasonic waves in the object or material tested. In most common UT applications, very short ultrasonic pulse-waves with center frequencies ranging from 0.1-15 MHz, and occasionally up to 50 MHz, are transmitted into materials to detect internal flaws or to characterize materials. A common example is ultrasonic thickness measurement, which tests the thickness of the test object, for example, to monitor pipework corrosion.

Radiographic testing

Industrial radiography is a modality of non-destructive testing that uses ionizing radiation to inspect materials and components with the objective of locating and quantifying defects and degradation in material properties that would lead to the failure of engineering structures.

Advantages and disadvantages

Advantages

Can be used anywhere, outside, in the workshop & in the water.

Can weld various types of materials.

Quick set-up and very easy to set up.

Can be used to weld all positions.

Electrodes are readily available in many sizes and diameters.

The equipment used is simple, cheap and easy to carry anywhere.

Low noise (rectifier).

Not very sensitive to corrosion, oil & grease.

Disadvantages

Welding is limited to the length of the electrodes and must be made to join.Every time you do the next welding, the slag must be cleaned.Cannot be used for welding non-ferrous steel materials.It is easy to oxidize due to the protective liquid metal, only the welding arc from the flux.The electrode diameter depends on the plate thickness and the welding position.

Conclusion

All things considered, SMAW welding is a really simple process which doesn't need excessive amounts of equipment. Clean your materials, then choose the correct electrode, arc length and weld speed, and you're starting out on the right foot. Having read through these SMAW welding tips and techniques, you're armed with everything you need to know – now learning to perfect strong, durable, high-quality stick welds is up to you!

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