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Comparative Analysis of Shielding Gas for GMAW and Method Study of NDT Testings

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Abstract: Welding defects can greatly affect weld performance and longevity. Having an understanding of the various defects, their causes and remedies can help to ensure higher-quality and longer lasting welds. Upon detection of welding defects, an evaluation should be carried out to determine its severity, and appropriate action taken. The change in shielding gas, the technique is used for reducing weld defects. CO_2 is used as a shielding gas in Gas metal arc welding. Trials were taken by using . Ar:CO_2 (80%:20%) as a shielding gas in Arm (2.4 m) & Upper centre frame Full welding by fabrication team. Proposal: . Ar:CO_2 (80%:20%) as a shielding gas

Index terms: Welding, Defects, Ar-CO_2.

1. INTRODUCTION

This article details some of the more common welding defects, their causes and possible preventative and corrective measures. Geometric imperfections refer to certain weld characteristics such as fit-up and weld bead shape as determined by visual inspection. They are an indication of poor workmanship and may be cause for concern if they exceed the acceptable limits of the quality control code being used for the weld inspection.

The defects in the weld can be defined as irregularities in the weld metal produced due to incorrect welding parameters or wrong welding procedures or wrong combination of filler metal and parent metal. Welding defects may result into the failure of components under service condition, leading to serious accidents and causing the loss of property and sometimes also life.

2. MAJOR WELDING DEFECTS

2.1 Crack

Cracking Cracks and planar discontinuities are some of the most dangerous especially if they are subject to fatigue loading conditions. They must be removed by grinding back (if superficial) or repaired by welding. Cracks can occur in the weld itself, the base metal, or the heat affected zone (HAZ).

Longitudinal cracks run along the direction of the weld and are usually caused by a weld metal hardness problem. This type of cracking is commonly caused by a cooling problem, the elements in the weld cooling at different rates. Longitudinal cracks can be prevented by welding toward areas of less constraint, preheating the elements to even out the cooling rates and by using the correct choice of welding consumables.

A transverse crack is a crack in the base metal beginning at the toe of the weld. They are caused by transverse shrinkage stresses, and often indicate a brittleness problem in the heat affected zone.

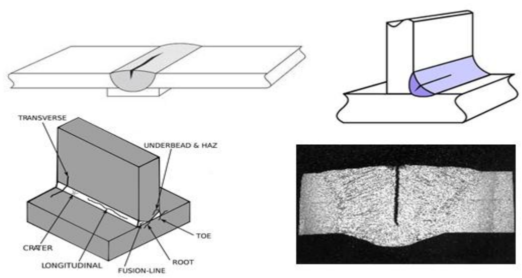

Fig-1 Welding Cracks

2.2 Porosity

Porosity is a collective name describing cavities or pores caused by gas and non-metallic material entrapment in molten metal during solidification. There are many causes which include contamination, inadequate shielding, unstable arc, arc gap too short and poor welding technique in general. Porosity can be minimized in many different ways- By the proper selection of electrodes and filler materials, improved welding techniques, proper selection of shielding gas. The effects of porosity on performance depend on quantity, size, orientation to stresses.

Fig-2 Porosity on weld

Reasons:

- Atmosphere contamination
- Excessively oxidized work piece
- The presence of foreign matter
- Inadequate or more shielding gas flow
- Severely clogged gas nozzle
- Damaged gas supply system

2.3 Incomplete Fusion/Penetration

Incomplete fusion or penetration is an internal planar discontinuity that is difficult to detect and evaluate, and very dangerous. It occurs when the weld metal does not form a cohesive bond with the base metal or when the weld metal does not extend into the base metal to the required depth, resulting in insufficient throat thickness. This defects are usually caused by incorrect welding conditions such as current too low, insufficient preheating, welding speed too fast, incorrect edge preparation, short arc length, insufficient electrode size or the arc was not in the centre of seam. This type of defects can only be repaired
by grinding/gouging out the defective area and re-welding.

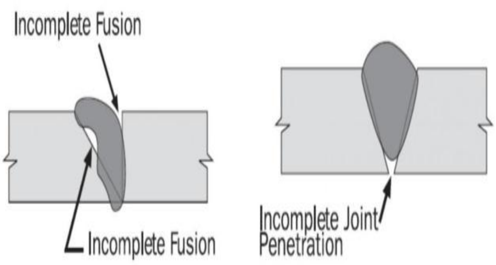

Fig-3 Fusion Defect

Reasons:

- Poor welding technique
- Travel speed too low

2.4 Spatters

Metal drops expelled from the weld that stick to surrounding surfaces. Spatters can be minimized by correcting the welding conditions and should be eliminated by grinding when present.

Fig-4 Spatters on weld

Reasons:

- Higher welding current
- Increased arc voltage
- Shorten the amount of stick out
- Change to an argon/carbon dioxide mixture if using a CO_2 shielding gas

3. PROBLEM STATEMENT

Inspection and testing of boom and arm of an excavator by using NDT test-

A) Ultrasonic Inspection.
B) Magnetic Particle Testing.

4. OBJECTIVE

1. To reduce cost & improve quality of weld behaviour for Ar-CO_2 Vs 100% CO_2 as shielding gas, keeping all other parameters to optimum level.
2. To detect internal or surface flaws.
3. To measure the dimensions of materials.
4. To control manufacturing processes.
5. To lower manufacturing costs.
6. To maintain uniform quality level.
7. To make a profit for the user.
8. To ensure customer satisfaction and maintain the manufacturer's reputation.

5. METHODOLOGY

5.1 Ultrasonic Testing (UT)

In ultrasonic testing high frequency sound waves are introduced into a material and they are reflected back from surfaces or flaws. Reflected sound energy is displayed versus time, and inspector can visualize a cross section of the specimen showing the depth of features that reflect sound. The reflected wave signal is transformed into electrical signal by the

transducer and is displayed on a screen. 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. If any dislocation is found in welds, it's located easily by using ultrasonic testing. 1. Types of Sound waves are
used for finding the dislocation in welds In solids, molecules can support vibrations in other directions so the numbers of different types (modes) of sound waves are possible. On the basis of particle displacement in the medium ultrasonic waves are classified as longitudinal waves, transverse waves, surface waves and lamb waves. Velocity remains the
same in the given medium but differs when the method of vibration changes.

There are four types of sound waves are used for finding the dislocation in welds:-

- Longitudinal - Parallel to wave direction
Transverse - Perpendicular to wave direction
- Surface (Rayleigh) - Elliptical orbit symmetrical mode
- Plate Wave (Lamb) - Component perpendicular to surface (extensional wave)

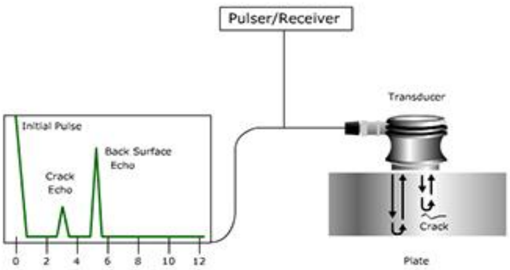

Fig-5 Ultrasonic testing

Main uses of Ultrasonic Testing Ultrasonic testing is sued to locate surface and subsurface defects in many materials including metals, weld metals, plastics, and wood. Ultrasonic inspection is also used to measure the thickness of materials and otherwise characterize properties of material based on sound velocity and attenuation measurements. [1]

5.1.1 Advantages of Ultrasonic Testing

- 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 high accuracy in determining reflector position and estimating size and shape.
- Minimal part preparation required.
- Detailed images can be produced with automated systems.
- Surface must be accessible to transmit ultrasound.
- Skill and training is more extensive than with some other methods.
- Materials that are rough, irregular in shape, very small, exceptionally thin or not homogeneous are difficult to inspect.
- Linear defects oriented parallel to the sound beam may go undetected.
- Reference standards are required for both equipment calibration, and characterization of flaws [1]

5.2. Magnetic Particle Inspection (MPI)

MPI uses magnetic fields and small magnetic particles, such as 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 affective. The method is used to inspect a variety of product forms such as castings, forgings, and weldments. Many different industries use magnetic particle inspection for determining a component's fitness-for-use.

5.2.1 Basic Principles of MPI

In theory, magnetic particle inspection (MPI) is a relatively simple concept. It can be considered as a combination of two non-destructive testing methods: magnetic flux leakage testing and visual testing. Consider a bar magnet. It has a magnetic field in and around the magnet. Any place that a magnetic line of force exits or enters the magnet is called a pole. A pole where a magnetic line of force exits the magnet is called a north pole and a pole where a line of force enters the magnet is called a south pole. [1]

5.2.2 Testing Procedure of MPI

- Cleaning.
- Demagnetization.
- Contrast dyes (e.g. white paint for dark particles).
- Magnetizing the object.
- Addition of magnetic particles.
- Illumination during inspection (e.g. UV lamp).
- Interpretation.
- Demagnetization - prevent accumulation of iron particles or influence to sensitive instruments.

- Magnetizing the object- There are a variety of methods that can be used to establish a magnetic field in a component for evaluation using magnetic particle inspection. It is common to classify the magnetizing methods as either direct or indirect.
- Direct magnetization: current is passed directly through the component.

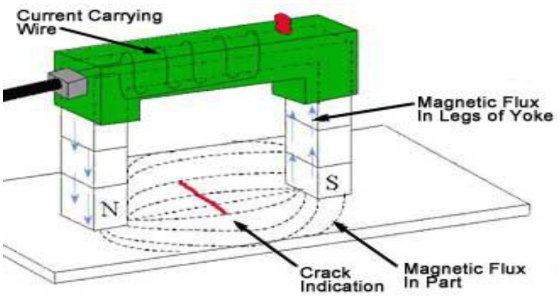

Fig-6 Magnetization using a permanent magnet Demagnetization

- After conducting a magnetic particle inspection, it is usually necessary to demagnetize the component. Remnant magnetic fields can:
- Affect machining by causing cuttings to cling to a component.
- Interfere with electronic equipment such as a compass.
- Can create a condition known as "ark blow" in the welding process. Arc blow may causes the weld arc to wonder or filler metal to be repelled from the weld.
- Cause abrasive particle to cling to bearing or faying surfaces and increase wear.[1]

5.2.3 Magnetic particles

- Pulverized iron oxide (Fe_3O_4) or carbonyl iron powder can be used.
- Colored or even fluorescent magnetic powder can be used to increase visibility.
- Powder can either be used dry or suspended in liquid.[1]

5.2.4 Advantages of MPI

- Fast, simple and inexpensive.
- Direct, visible indication on surface.
- Unaffected by possible deposits, e.g. oil, grease or other metals chips, in the cracks.
- Can be used on painted objects.
- Surface preparation not required.
- Only good for ferromagnetic materials.
- Sub-surface defects will not always be indicated.
- Relative direction between the magnetic field and the defect line is important.
- Objects must be demagnetized before and after the examination.

6. TYPES OF TESTING

1. Visual Inspection
2. Magnetic particle testing.
3. Ultrasonic Inspection

7. METAL ARC WELDING

Shielded metal arc welding (SMAW), also known as manual metal arc welding (MMA or MMAW), flux shielded arc welding[or 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 work piece 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.

7.1 Shielding Gas

1:- CO_2 is used as a shielding gas in Gas metal arc welding.
2:- Trials were taken by using . Ar:CO_2 (80%:20%) as a shielding gas in Arm (2.4 m) & Upper center frame Full welding by fabrication team.
3:- Proposal: . Ar:CO_2 (80%:20%) as a shielding gas

8. EXPERIMENTATION

8.1 Ar:CO_2 (80%:20%) Shielding Gas For Gas Metal Arc Welding

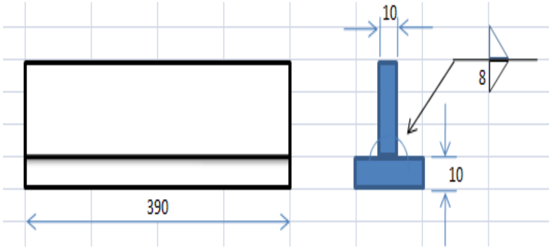

Fig-7 Weld test piece specimen

8.1.1 Parameters:

Current - 315 A
Voltage - 29.5 V
Gas flow 20~25 lpm

Welding Electrode Specification:
*Type -AWS- 5.18-ER70S-6
*Wire DIA. - 1.2 mm

Table-1 Trial Results

Sr. no	Description	Shielding Gas	
		Ar-CO_2 (80-20 %)	CO_2-100%
A	Specimen weight before welding	3.1	3.1
B	Specimen weight after welding	3.352	3.392
C	Weld bead metal (Kg) (B-A)	0.252	0.292
D	Welding wire consumed for 780mm length	0.275	0.335
E	Spatter Loss (Kg) (D-C)	0.029	0.041
F	Time required in sec	150	164
G	Gas consumed in litre	50	56

8.2 Spatter from Ar-CO_2 mixture & 100% CO_2 Generation

In fig-8 graph shows filler wire consumed and spatter loss and 22% more wire consumed and 48% more spatter formed in case of 100% co2 gas as compared to Ar:CO_2 (80:20) Gas[8]

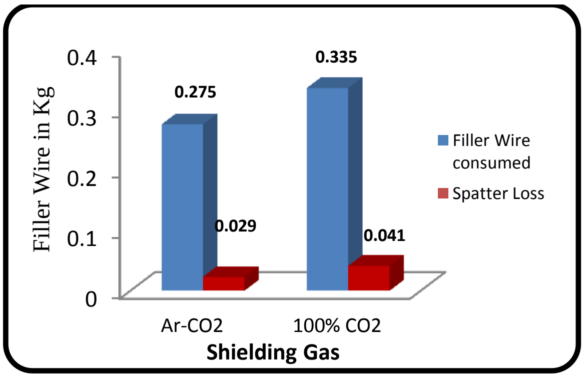

Fig-8 Filler wire consumed and spatter loss

8.3 Welding Spatter Comparison

In fig-8 shows the spatter formation in 100% CO_2 and Ar:CO_2 (80:20). More welding spatter form in 100% CO_2 [8]

Fig-9 Welding Spatter

8.4 Travel Speed

In fig-10 analysis 11% slow travel speed in 100% CO_2 than Ar:CO_2 (80:20) :-[8]

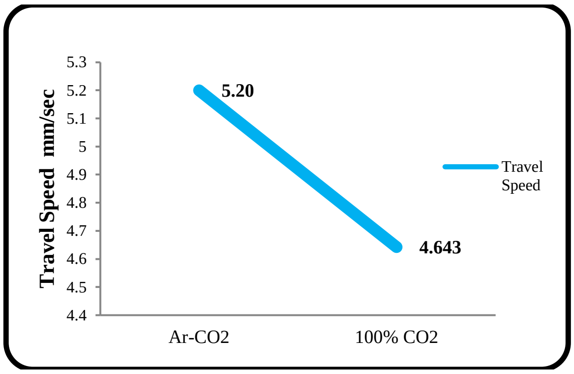

Fig-10 Shielding Gas

8.5 Shielding Gas Consumption

In fig-11 represents 13% more gas consumption in 100% CO_2 than Ar:CO_2 (80:20) :- [8]

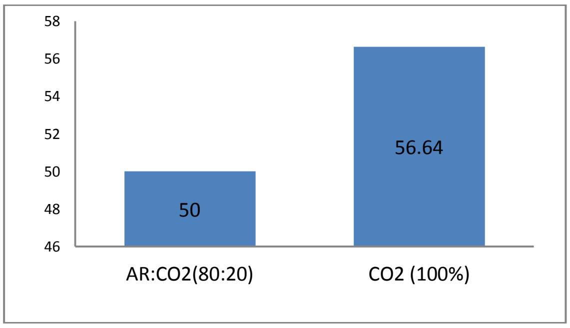

Fig-11 Shielding Gas Mixture

8.6 Test Specimen Parameters

For Ar-CO_2 (80-20%)
Voltage: 26-28 V
Current: 280-296 A

For 100 % CO_2
Voltage: 28-30V
Current: 300-310 A

Table-2 Summary

Sr. no	Parameters	Ar:CO_2 (80%:20%) Ref	CO_2 (100%)	Remark
1	Travel Speed (mm/sec)	5.20	4.643	11% More in Ar:CO_2
2	Deposition efficiency	91.64	87.76	4% More in Ar:CO_2
3	Spatter generation (kg)	0.029	0.041	48% Less in Ar:CO_2
	Filler wire (kg)	0.275	0.335	22% Less in Ar:CO_2
5	Shielding gas consumption (lit)	50	56.64	13% Less in Ar:CO_2
6	Fume formed (mg/g)	4	12	-----
7	Weld bead appearance	Very Good	Good	-----

Table-3 Overall Cost Comparison

Sr. no		Description	Shielding Gas	
			Ar:CO_2	CO_2
1	Shielding Gas	Cost of shielding Gas (Rs/m^2)	30.88	18.4
2		Shielding gas flow (lpm)	22	22
3		Shielding gas consumption (m^3)	307.0707	206.7424
4	Power	Current(Avg.) A	290	310
5		Voltage (Avg.) V	28	30
6		Power (Kw)	8.12	9.3
7	Filler Wire	Welding wire consumption	28	34.16
8		Welding wire rate / kg	74	74

8.7 Overall Costing

- Cost Saving per ARM : Rs. 532
- Daily ARM production :- Approx. 10
- Daily Cost saving : 532*10 = Rs. 5320
- Monthly ARM production:- Approx. 300
- Monthly Cost Saving :- 5320*30 = Rs. 159600

9. CONCLUSION

During the comparative analysis of shielding gas for GMAW and method study of NDT testing for boom and arm of an excavator, it was found that:-

- Spatter formation: 48% more spatter formed in case of 100% CO_2 gas as compared to Ar:CO_2 (80:20) Gas
- Travel Speed: In this analysis 11% slow travel speed in 100% CO_2 than Ar:CO_2 (80:20)

- Shielding Gas Consumption: 13% more gas consumption in 100% CO_2 than Ar:CO_2 (80:20)
- Power consumption: 14% more power consumed in 100% CO_2 than Ar:CO_2 (80:20)
- Welding wire consumption: 18% more wire consumed in 100% CO_2 than Ar:CO_2 (80:20)
- Hence we conclude that the mixture of shielding gas (Ar:CO_2 80:20 %) is more suitable than (100% CO_2)

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