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"To study the Effect of consumable electrodes and the effect of shielding gases on Stainless steel welding – A State of review"

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Abstract:-

The aim of this study is to study the effect of different consumable electrodes and different shielding gases on stainless steel welding. It is essential to select a particular electrode as well as shielding gas combination, which will give a good weld joint.Shielding gas composition and gas flow rate affects the penetration and cross-sectional area.The basic purpose of shielding gas is to protect weld from contamination. The role of consumable electrodes and shielding gas in stainless steel welding is to generate the arc plasma and stable arc root mechanism and also to solidify the weldment smoothly so there will be better penetration and bead geometry.

Study:-

Air in the weld zone is displaced by a shielding gas in order to prevent contamination of the molten weld puddle. This contamination is caused mainly by nitrogen, oxygen and water vapour present in the atmosphere.

The shielding gas used must possess the following properties

• Generate the arc plasma and stable arc root mechanism.

• Produce smooth detachment of molten metal from the tip of the wire.

• Protect the wire tip, molten pool and welding head in the immediate vicinity of the arc from oxidation.

To avoid the problems associated with contamination of the weld puddle, three main gases are used for shielding. These are argon, helium and carbon dioxide. In addition, small amounts of oxygen, nitrogen and hydrogen have proven beneficial for some applications. Of these gases, only argon and helium are inert gases, compensation for the oxidizing tendencies of other gases are made by special wire electrode formulations. Argon, helium and carbon dioxide can be used alone, in combinations or mixed with others to provide defect free welds in a variety of weld applications and weld processes. Pulsed arc technique is an artificial method of producing spray transfer at currents below those at which spray transfer occurs naturally. However, to obtain this, it is essential to select a particular electrode/shielding gas combination, which will give a natural spray transfer. For example, a mild steel electrode used with CO_2 will not give a natural spray transfer, but the same electrode used with argon will.99.95% commercially pure argon is used primarily for weldingaluminum, but is not recommended for material such as steelsbecause of poor arc stability. Argon +O_2 gas mixture producesa constrictive arc, which makes it ideal for stabilizing the sprayor pulsed metal transfer modes. The 'tight' arc, however, meansthat attention must be paid to joint fit-up and is less tolerant tosurface contamination on thin sheet than argon 5% CO_2, 2%O_2.For general applications, additions of CO_2 are preferred toO_2 as the arc is less constricted and the resulting weld bead hasa better profile. For material of less than 6mm thickness, argon with 5% CO_2, 2% O_2 produces minimal spatter. For thicker materials, higher CO_2 contents are preferred to reduce risk ofsidewall fusion defects, but unfortunately spatter does increase.For this argon 15% CO_2, 2%O_2 has been found to produce thebest performance in terms of good weld bead penetration andlow spatter generation. Apart from pure argon itself there are two mixtures, Argonex 1 (99% pure Ar 1% O_2) for high alloy ferrous materials and Argo shield 5 (95% low cost Ar and 5%CO_2), for low alloy ferrous materials including MS and stainless steels used for welding SS to mild steels or for overlaying of SSon mild steel are commonly used for pulsed arc. Ninety nine percent pure argon,1%O_2 mixture is mainly used with the high alloy ferrous materials. The purpose ofO_2 addition is to improve "wetting" of the weld pool without leading to any significant loss of the more reactive elements. Ninety five percent low cost argon and 5% CO_2gas mixture has been designed to suit low alloy ferrous materials including mild steel. The 5% CO_2 is added to give improved "wetting" and also to prevent the formation of gas pores in the weld metal. A mixture of 95% Ar and 5% CO_2 has been found to give least spatter and best bead appearance[1]

Table 1.1 Shielding gas recommendations

Steel type	Gas flow 12–16 (l/min)
Duplex	Ar + 2% O_2 or Ar + 30% He + 2.5% CO_2
Standard austenite	Ar + 2% O_2 or Ar + 2–3% CO_2
Heat resisting	ArorAr + 30% He
Fully austenite	Ar or Ar + 30% He

Table 1.2 Recommended combinations of shielding gases and electrodes for pulsed arc welding

Electrode type	Gas type
Simple Mn–Si deoxidized mild steel	Argo shield 5
Cr–Mo steel	Argo shield 5
Low and extra low C stainless and heat resisting steels	Argo nox 1
Medium carbon heat resisting steels	Argo shield 5
Stainless steel (used for welding SS to mild steels) or for overlaying on mild steel	Argo shield 5
Aluminium and alloys	Argon
Ni alloys	Argon
Copper	Argon
Bronzes	Argon
Bronzes used for overlaying steels	Argonox 1

Researchers examined GMAW dissimilar welding of AISI 409 ferritic stainless steel to AISI 316L austenitic stainless steel by using AISI 308 filler wire and Argon shielding gas. They studied and analyzed the effects of welding parameters: welding current, gas flow rate and nozzle to plate distance, on ultimate tensile strength (UTS) and Yield Strength (YS) in MIG welding of AISI409 ferritic stainless steel to AISI 316L Austenitic Stainless Steel materials. Experiments have been conducted as per L9 orthogonal array of Taguchi method. The observed data of UTS and YS have been interpreted, discussed and analyzed with use of Taguchi Desirability analyses.And then visual inspection and X-ray radiographic test of all welded specimens have been made. After visual inspections and X-ray radiographic test, tensile test specimens have been prepared from the welded joints, by cutting/machining for conducting tensile test. During cutting/machining of the tensile test specimens, small cut- outs have been taken. These cut pieces have then been ground, polished and etched for studying microstructures.Lack of fusion at root or wall has occurred due to improper setting of the welding input parameters: current, improper cleaning, faster arc travel speed, presence of oxides, scale, etc, which do not permit the deposited metal to fuse properly with the base metal. Heat input should be optimum to prevent lack of fusion defect. Too low heat input does not ensure proper melting of the weld deposit whereas, too high heat input, makes the large weld pool, from which metal starts flow away in the area in front of the arc whichprevents melting of the base metal. Porosity defect has been found in some samples due to gas being entrapped in the solidifying metal. Porosity may detrimental effects on quality of weldment. The contamination of the shielding gas, filler metal and base metal may be the major problem. Leaks anywhere in the distribution system allow the air to diffuse into the shieldinggas. Molten weld metal holds a lot of nitrogen, oxygen and hydrogen than the base metal. As the weld puddle freezes, the gases come out of solution and form porosity. Porosity can also be caused by excessive tip-to-work distance which can create turbulence in the shielding gas column, aspirating oxygen and nitrogen from the atmosphere which then react with the high temperature weldmetal. A too low or too high gas flow rate also enhances porosity. At low rates, the gas cannot exclude the atmosphere. At high flows, turbulence in the gas column causes mixing with the atmosphere. From the results of visual inspection and X-ray radiographic tests, it is noticed that some consistency in the findings can be identified. Visual and X-ray radiographic tests also indicate that some sample has got no significant defect. The objective of this research was to do Optimization of the process parameters has been done by using Taguchi-Desirability analysis; optimum parametric combination has been determined[2]

Researchers had studying the effect of shielded metal arc welding, gasmetal arc welding and gas tungsten arc welding on tensile and impact properties of ferritic stainless steel conforming to AISI 409M grade. Rolled plates of 4 mm thickness were used as thebase material for preparing single pass butt welded joints. 99.9 % Argon gas was used as shielding gases and AISI 308L used as consumables electrode in case of GMAW. Tensile and impact properties, microhardness, microstructure and fracture surface morphology of the welded joints have beenevaluated and the results compared. This is mainly due to the presence of finer grains in the fusionzone and heat-affected zones.Carbon and Nitrogen affect the impact properties of the heat affected zone (HAZ) in chromium steels –FSS. The tensile and impact fracturesurface of ASS weld metal joints show ductile fractureirrespective of welding processes.

Table1.3: - Chemical composition (wt-%) of base metal and weld consumable

Material	C	Mn	P	S	Si	Cr	Ni	Ti	Mo	Cu	Fe
Base metal (AISI 409M)	0.028	1.10	0.030	0.010	0.40	10.90	10.39	0.004	-	-	Bal
Weld consumable ASS (AISI 308L)	0.035	0.082	0.018	0.015	0.67	19.00	11.00	-	0.01	0.1	Bal

From this investigation, it was found that gas tungsten arc welded joints showed superior tensile and impact properties compared with the shielded metal arc and gas metal arc welded joints.[3]

Here Researchers had studying the effect of shielded metal arc welding, gas metal arc welding and gas tungsten arc welding on tensile and impact properties of ferritic stainless steel conforming to AISI 409M grade using Duplex Stainless Steel (AISI 2209) as consumable electrodes. . Rolled plates of 4 mm thickness were used as the base material for preparing single pass butt welded joints. 99.9 % Argon gas was used as shielding gases in case of GMAW. From this investigation it is found that gas tungsten arc welded joints of ferritic stainless steel have superior tensile and impact properties compared with shielded metal arc and gas metal arc welded joints and this is mainly due to the presence of finer grains in fusion zone and heat affected zone.

Table1.4:- Chemical composition (wt-%) of base metal and weld consumable

Material	C	Mn	P	S	Si	Cr	Ni	Ti	Mo	Cu	Fe
Base metal (AISI 409M)	0.028	1.10	0.030	0.010	0.40	10.90	10.39	0.004	-	-	Bal
Weld consumable Duplex Stainless Steel (AISI 2209)	0.030	0.80	0.018	0.016	0.80	22.00	09.00	-	3.0	-	Bal

From this investigation, it was found that gas tungsten arc welded joints showed superior tensile and impact properties compared with the shielded metal arc and gas metal arc welded joints.[4]

The influence of flux cored arc welding (FCAW) process parameters such as welding current, travel speed, voltage and CO_2 shielding gas flow rate on bowing distortion of 409M ferritic stainless steel sheets of 2 mm in thickness was discussed. The bowing distortions of the welded plates were measured using a simple device called profile tracer. An experimental regression equation was developed to predict the bowing distortion and with this equation, it is easy to select optimized process parameters to achieve minimum bowing distortion. It is revealed that theFCAW process parameters have significant influence on bead profile and the bowing distortion.

Table1.5:- Chemical composition (wt-%) of base metal and weld consumable

Material	C	Mn	P	S	Si	Cr	Ni	Ti	Mo	Cu	N
Base metal (AISI 409M)	0.027	0.953	0.02	0.008	0.588	11.89	0.326	0.75	-	0.13	0.03
Weld metal (AISI 309LT-1)	0.048	1.23	0.02	0.006	0.64	22.03	12.11	-	0.09	0.13	-

CO_2 shielding gas flow rate which affect bowing distortion were identified. It is concluded that Bowing distortion decreases linearly with increase in shielding gas flow rate due to increase in penetration. The interaction of shielding gas flow rate and welding current, shielding gas flow rate and voltage and welding speed and voltage on bowing distortion are significant. The shielding gas flow rate alters bead width to little extend. SS409 given best results on welding with Shielding gas CO_2.[5]

Researchers investigated that to overcome the problem of corrosion in metals two different materials Stainless Steel 409 and Stainless Steel 439 are welded by TIG welding and studied. This dissimilar material with property of high corrosion resistant and thus this ferritic material provide better facility of corrosion resistant which gives the opportunity of using it on different fields which are highly prone to corrosion areas. Stainless Steel 409 and Stainless Steel 439 are welded by TIG welding. Argon gas used as shielding gas. Nowadays corrosion is the major downturn for the automotive industries and for automotive holders. The chances of corrosion are getting increased more during the warranty period, as a result it have attracted many customers and car makers. Due to the cyclic condensation and oxidation of exhaust gasses, the parts of the vehicles like mufflers of vehicles exhaust system are usually subjected to corrosion failure. That's why it is necessary and mandatory to clarify the corrosion behaviour and to improve the corrosion effecting of stainless steel which is used for exhaust systems. Automotive exhaust gas mostly contains CO_2, H_2O, O_2, CO, HC, NOx and SO_2. But SO_2 is the main cause for the failure through condensation process, which mainly comes from the sulphur in the fuel. This is to increase the effort of corrosion and to balance the cost of the material and to make it economically feasible.

Table1.6: - Chemical composition (wt-%) of base metal and weld consumable

Material	C	Mn	P	S	Si	Cr	Ni	Ti	Mo	Cu	Al
Base metal (AISI 409M)	0.020	1.305	0.024	0.005	0.525	11.60	0.12	-	-	-	-
Base metal (AISI 439)	0.022	0.737	0.003	0.011	0.431	17.21	0.321	0.452	-	-	0.009
Weld metal (AISI 309L)	0.04	0.6	0.04	0.03	0.9	22	13	-	0.75	0.75	-

The corrosion resistance is done by performing welding of these two dissimilar metals by using electrode 309L. After the welding is performed properly it is forwarded to proceed further tests like tensile test, Rockwell hardness test, macro examination test, micro examination test and corrosion resistance test. The examination is done on various regions. While doing the examination on SS 409 parent it was observed that micro examination of the parent region revealed grains of ferrite with particles of alloy carbides present in the ferritic matrix It is observed that the heat is travelling throughout theplate. Whereas this temperature will not affect the metal to change its form but it shows that its thermal conductivity is quite higher. From the simulation for heat flux it is observed that the heat flux generated over the bevelled region during welding is about 8.2102e5 W/m^2[6]

Ar is the most common protective gas used in GMA welding and by mixing with 15–25 wt% CO_2 gas the depth of penetration and size and geometry of weld seal are reached the desired forms. Therefore, the preferred protective gas is Ar + CO_2 gas mixture in industry.[7]

Identification of significant process parameters using experiments needs to be carefully formulated as it can be a resource demanding process. Using appropriate statistical techniques such as the Taguchi method of factorial design of experiments, the number of necessary experiments can be reduced and the statistical significance of parameters can be safely identified.[8]

Arc welding process plays an important role in manufacturing. Metal inert gas (MIG) welding is one of the most significant arc welding processes.[9]

In TIG welding inert gases like argon, helium are used which acts as shielded gases because they prevent atmospheric contamination of molten weld pool and also they do not react with the base metal. This shielding gas acts as a blanket to the weldment and excludes active properties surrounded in the air. TIG welding results in increase in the weld penetration in the austenitic stainless steel and penetration overcomes as a result of chemical composition. [10]

N_2-containing shielding gas or filler metal should be used to suppress and compensate the nitrogen loss. Considering that there are no mature high nitrogen welding materials. It is a very common method to use N_2-containing shielding gas. Most researches that added N_2 to the shielding gas mainly aims to increase and stabilize the austenite of the weld and the hardness of the solidified zone and the corrosion resistance of the joint can be thereby enhanced. The addition of N_2 to the shielding gas can also effectively suppress the formation of pores compared to pure Ar. As the increasing of N_2, the stability and the quality of the weld also decreases, which makes the welding spatter become serious. The ability of O_2 to promote nitrogen dissolution to the weld from N_2-containing shielding gas is stronger than CO_2. O_2 is thereby selected as the oxidizing gas. The tensile strength of the joint is improved after using N_2-containing shielding gas. Also N_2containing shielding gas gives ferrite reduction and the uniformity of the weld. The main function of N_2-containing shielding gas in the process of fusion welding is to suppress the escape of nitrogen to increase uniformity of the weld microstructure.[11]

Table 1.7 Chemical composition of 308L electrode

Material	C	Mn	P	S	Si	Cr	Ni	Mo	Cu	Fe
AISI 308L	0.04	0.5-2.5	0.04	0.03	0.9	18-21	9-11	0.75	0.75	Bal

Table 1.8 Chemical composition of 309L electrode

Material	C	Mn	P	S	Si	Cr	Ni	Mo	Cu	Fe
AISI 309L	0.04	0.5-2.5	0.04	0.03	0.9	22-25	12-14	0.75	0.75	Bal

Table 1.9Tabular Summery of Stainless Steel 409 welding

Reference No.	Welding process	Plate thickness	Weld Consumable electrode	Input Parameters with ranges	Output Parameters	Shielding gases
2	GMAW	3 MM	AISI 308	Welding current A (100,112,124), gas flow rate l/min (10,15,20) and nozzle to plate distance mm (9,12,15)	UTS and Yield strength	Pure Argon
3	SMAW,GMAW and GTAW	4 MM	ASS (AISI 308L)	SMAW,GMAW and GTAW - Welding Current A (90,120), arc voltage V (20,25,30), welding speed mm/min (110,120,130), Heat transfer efficiency (0.7,0.75) Net heat input Kj/mm (0.623,1.05,1.423) Electrode Dia mm (1.6,2.0,3.15)	Tensile. Impact and Hardness	Argon
4	SMAW,GMAW and GTAW	4 MM	Weld consumable Duplex Stainless Steel (AISI 2209)	SMAW,GMAW and GTAW - Welding Current A (90,120,150), arc voltage V (22,25,30), welding speed mm/s (2.5,3,4), Net heat input J/mm (800,1000,1125) Electrode Dia mm (1.6,2.0,4)	Yield strength, Tensile Strength and % of elongation	Argon
5	Flux cored arc welding	2 MM	AISI 309LT-1	-welding current A (60,70,80,90,100) travel speed mm/s (4,5,6,7,8), voltage V (16,18,20,22,24)and shielding gas flow rate l/min (10,12,14,16,18)	Bowing distortion	Argon + CO_2
6	GTAW	10 MM	AISI 309L	-Welding current A (142,181,184), Voltage V (20,21), Gas flow rate l/m (14,15), Travel speed sec/mm (91,92,93,94,95,98)	Weld bead size, total cooling rate, total heat flux	Argon

Conclusion:-

Electrode 308L has better combination with Stainless steel and gives better weld penetration and quality.Electrode 309L can produced greater tensile strength.Shielding gas has several functions during welding likes - Protection of weld from atmospheric gases like O_2, N_2, H_2, etc., Creating environment for stable arc and Smooth molten metal transfer.Shielding gas types also have effects on penetration, 100% carbon-dioxide (CO_2) or 100% helium (He) turns out a wider and more profound penetration. The optimum value of arc voltage gives better penetration weld results. Shielding gas composition and gas flow rate affects the penetration and cross-sectional area. The manner by which shielding gas composition and gas flow rate affect penetration and cross-sectional area is based on method of the arc gap adjustment. Carbon and Nitrogen affect the impact properties of the heat affected zone (HAZ) in chromium steels. It was studied that that desirable weld cross-sectional geometry was obtained with pure argon shielding gas. The heat input intensities with rise in shielding gas flow rate not considering the shielding gas. Increase in the shielding gas flow rate results in decrease in bowing distortion. Furthermore shielding gas spreads wider, on leaving from the nozzle, due to increase in the shielding gas flow rate. There is high probability of recombination at cooler regions of the arc and results in increase in weld bead width. The number of argon gas molecules increases with the increase in shielding gas flow rate and results in increase of heat input.Shielding gas types also have effects on penetration. Shielding gases with a superior rate of thermal conductivity, for instance 100% carbon-dioxide (CO_2) or 100% helium (He) turns out a wider and more profound penetration. Despite the fact that shielding gases has a lower rate of thermal conductivity, for instance l00% argon (Ar), or an Ar / CO_2 a united shallow penetration is achieved.

The effect of N_2 gas as shielding gas:-

- Increasing the stainless steels mechanical properties.
- increases corrosion resistance
- The addition of N_2 to the shielding gas can also effectively suppress the formation of pores compared to pure Ar.

The drawbacks of O_2gas as shielding gas:-

- The use of oxygen as active gas induces some drawbacks like higher price, and danger associated to the use of oxidize

The drawbacks of CO_2gas as shielding gas:-

- A thinner gangue consisting mainly of hematite having a more insulating nature is observed for the Ar/CO_2 mixtures.

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