



Effect of Shielding Gases on Weld Quality in GTA & GMA Welding- A Review

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ARTICLE INFO

Article history:

Received: 28 September 2015;

Received in revised form:

27 November 2015;

Accepted: 01 December 2015;

Keywords

GTAW,
GMAW,
Shielding Gas,
Weldability,
Steels,
Mechanical Properties,
Microstructure,
SEM etc.

ABSTRACT

Mechanical Properties such as tensile strength, yield strength Impact strength etc and microstructure of weldment of various steels are too much affected by the shielding gases. Shielding gases play an important role during the welding process.it cannot be over look. In this review paper an attempt has to be made to explain the effect of shielding gases on the mechanical properties and metallurgical properties of a weldment. The coarse-grained weld microstructure, higher heat-affected zone, and lower penetration together with higher reinforcement reduce the weld service life in continuous mode gas metal arc welding (GMAW). It is observed that weld bead geometry and penetration is too much affected by the use of shielding gas. This brief review illustrates the effect of shielding gases on weld quality.

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Introduction

Welding plays a significant role in the fabrication, erection and commissioning of plants and machinery for power, petroleum, chemical, steel and other industrial sectors and weldments are too much affected by the use of a shielding gas or mixture of shielding gases. For shielding purpose different types of gases are used such as Argon, Helium, mixture of Ar+He, CO₂ are used during the welding process. For different welding process different shielding gases are used [1].

Welding of Stainless steel

GTA Welding

R.-I. Hsieh et al [2] studied the effect of Minor Elements and Shielding Gas on Penetration in TIG Welding of Type 304 Stainless Steel and found that oxygen and sulfur are beneficial in increasing a depth/width ratio because of the increased surfacetension/temperature gradient. Elements, such as aluminum, that have a deleterious effect on the depth/width ratio will combine with oxygen and reduce the soluble oxygen content in the weld pool. On the other hand, silicon and phosphorus have a minor effect on the depth/width ratio. Shielding gas using Ar + 1% O₂ or Ar + 5% H₂ can significantly promote the depth/width ratio Fig.1-3

M.T. Liao and W.J. Chen [3] examines how the microstructure and mechanical properties of 304 stainless steel welds are influenced by the shielding gas. The spatter rates increase as the CO₂ content of the Ar+CO₂, shielding-gas mixtures increases from 2 to 20%. The notch toughness of all the weld metals is affected by the delta-ferrite and oxygen potential. At room temperature, the notch toughness property is strongly dependent on oxygen potential and finally they conclude that composition of shielding gas has a significant

effect on the microstructure and mechanical properties of 304 stainless steel welds. The 98%Ar + 2% CO₂ and the 98%Ar + 2% O₂, mixtures create a stable spray arc with few spatters. In the 98%Ar+ 2%O₂ mixture, there is no CO₂ gas, therefore the carbon content of the weld deposits is not increased and the amount of ferrite is the highest.

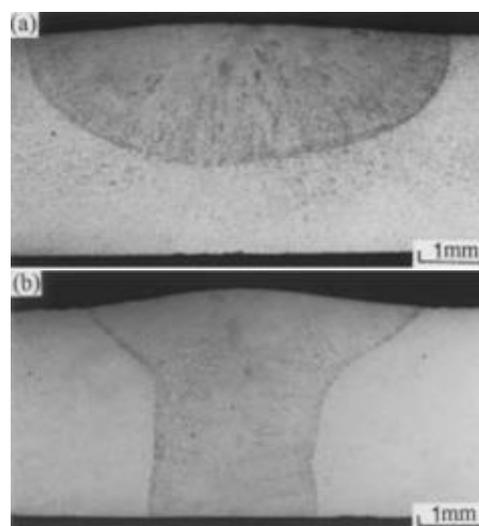


Fig 1. Macrosection of TIG bead-on-plate weld showing the Effect of oxygen content of base metal on the Weld geometry. (a)70 ppm. (b) 120 ppm[2]

The notch toughness of all the weld metals is affected by the delta-ferrite and oxygen potential. At room temperature, the notch toughness property is strongly dependent on oxygen potential. At - 196°C, both delta-ferrite and oxide inclusions are

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detrimental to the notch toughness properties, but the delta-ferrite plays a much more important role at this temperature. Twins in the austenite matrix of the weld metal are also observed.

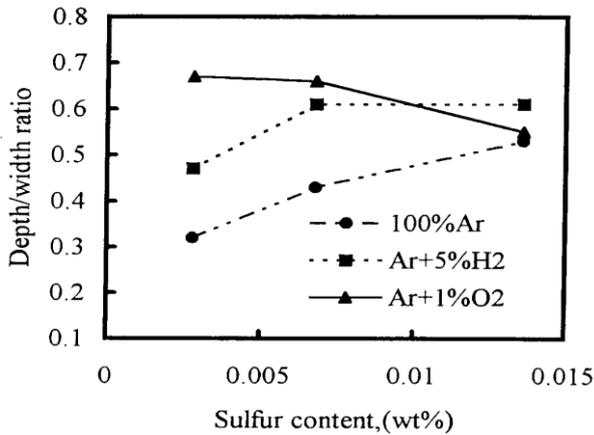


Fig 2. The effect of shielding gas on the weld d/w ratio at a variety [2]

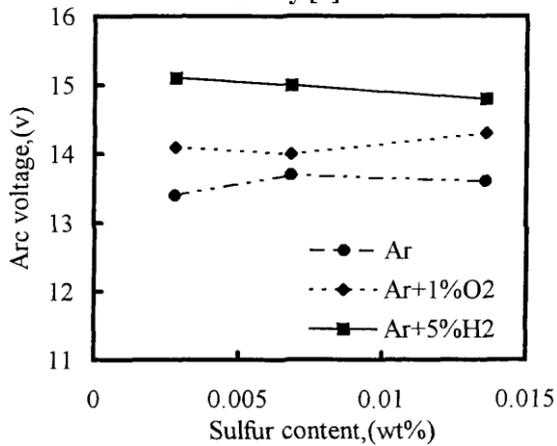


Fig 3. The effect of shielding gas on the arc voltage at a variety of Sulfur contents of sulfur contents [2]

V. V. Cay, et al [4] studied SAE 1020 steel for alloyed. Two different types of shielding gas compositions during the alloying process, the study investigated the effects of modified shielding gas composition on the microstructure, hardness, and abrasive wear resistance of specimens. It was observed that with modifications in shielding gas composition, the microstructure and volume hardness of the specimens changed and no cracks and voids were formed in the interface area and the formulated that changes in shielding gas composition in surface alloying process significantly affect specimens' microstructure and mechanical properties. Fig.4

Table 1. Welding and process parameter

Specimen number	Coating powder	Thickness (mm)	Energy intensity, A	Hardness (HRc)	Shielding gas
1	FeCr	1.50	100	58.15	Argon
2	FeCr	1.50	100	56.70	Argon + 3% H ₂
3	FeMo	1.50	100	50.50	Argon
4	FeMo	1.50	100	52.30	Argon + 3% H ₂
5	FeTi	1.50	100	43.15	Argon
6	FeTi	1.50	100	45.30	Argon + 3% H ₂

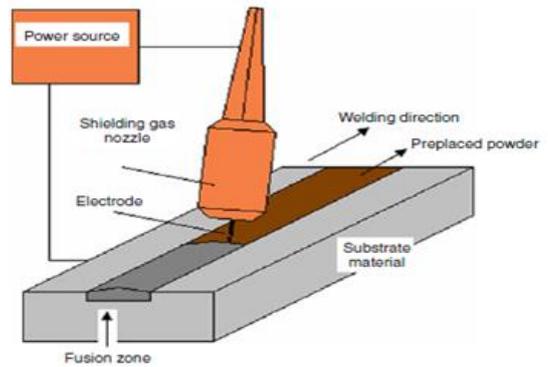


Fig 4. Process Diagram of Tungsten Inert Gas (Tig) Welding [4]

P. Sathiya and et al [5] employed Gas tungsten arc welding (GTAW) for welding of thin sheets/ plates. The GTAW process ensures small amounts of slag formation during welding, which eliminates slag crevices and sites for corrosion attack. Standard 2205 (UNS S31803) DSS sheets of 5 mm thickness, with 22.37% Cr and 5.74% Ni, were used in this study. Weld beads were produced with Zeron-100 super DSS filler wire with higher alloy content (26% Cr and 8% Ni). Argon (Ar) and helium (He) were employed as shielding gases. The ferrite number of the weld metal for the two different shielding gases was investigated. Mechanical properties of joints such as impact strength and hardness were evaluated. Microstructure evaluation was also carried out. Fig.5 & 6

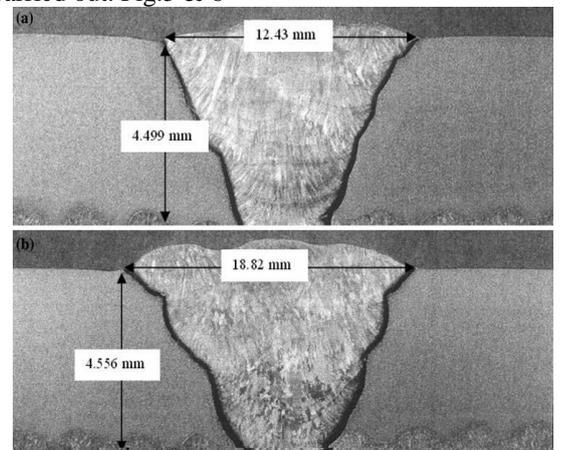


Fig 5. Weld bead profile: a argon shielding gas and b helium shielding Gas [5]

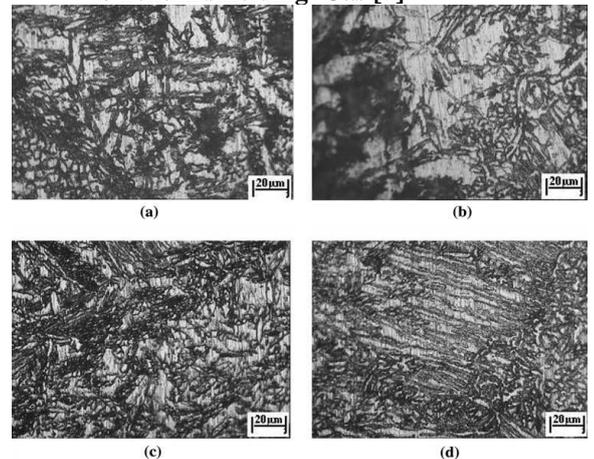


Fig 6. Weld metal and HAZ microstructures. a Argon shield, weld Metal (200x). b Argon shield, HAZ (200x). c Helium shield, weld Metal (200x). d Helium shield, HAZ (200x) [5].

And finally they conclude that when using the helium shielding gas the weld bead aspect Ratio (width/penetration) is higher than in the Ar-shielded weld and Helium-shielded welds Exhibited higher toughness due to the large Mn content and the smaller amount of ferrite phase And larger amount of austenite phase present in the weld metal, Chromium nitride precipitation is observed in the argon-shielded weld metal, the hardness of the weld metal is much higher than that of the BM and HAZ for both studied shielding gases.

Ahmet Durgutlu [6] studied, the effect of hydrogen in argon as shielding gas was investigated for tungsten inert gas welding of 316L austenitic stainless steel. The microstructure, penetration and mechanical properties were examined. Pure argon, 1.5% H_2 -Ar and 5% H_2 -Ar were used as shielding gas. The highest tensile strength was obtained from the sample which was welded under shielding gas of 1.5% H_2 -Ar. After bending test, cracks, tearing and surface deflection were not observed on the samples that were welded under all three shielding media. Mean grain size in the weld metal increased with increasing hydrogen content. Additionally, weld metal penetration depth and its width increased with increasing hydrogen content.

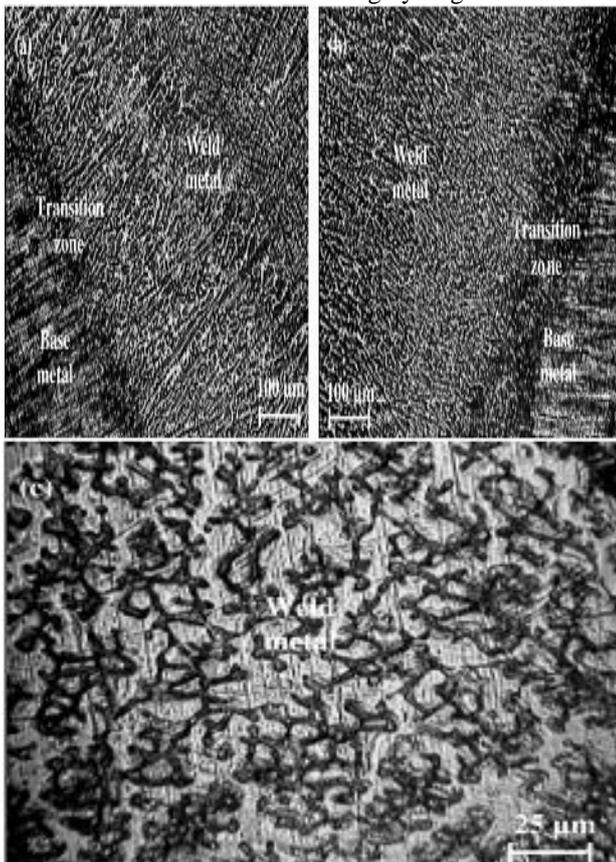


Fig. 5. Optical photomicrographs of sample welded under pure argon [6]

GMA Welding

Mohamad Ebrahimnia and et al, [7] studied the influence of variation in the shielding gas composition on the weld properties of the steel ST 37-2t After accomplishing some mechanical and metallographic tests, it was found that the absorbed energy in the Charpy impact test first increases then remains constant with increase of the amount of carbon dioxide in the shielding gas composition. The amount of inclusions decreases and the Widmanstatten ferrite volume fraction increases with increase of the carbon dioxide percent in shielding gas. On the other hand, the depth of the fusion zone in GMAW increases with increase of the carbon dioxide in shielding gas. Fig.7& 8

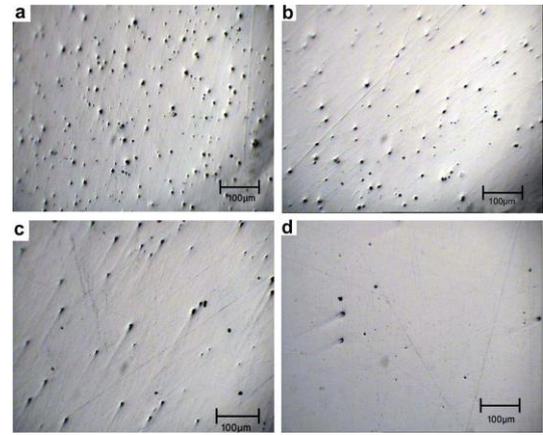


Fig 7. Comparison between amounts of inclusion in different samples. (a) S1 (97.5% Ar + 2.5% CO_2), (b) S2 (90% Ar + 10% CO_2), (c) S3 (82% Ar + 18% CO_2), and (d) S4 (75% Ar + 25% CO_2), samples are in an etched state [7]

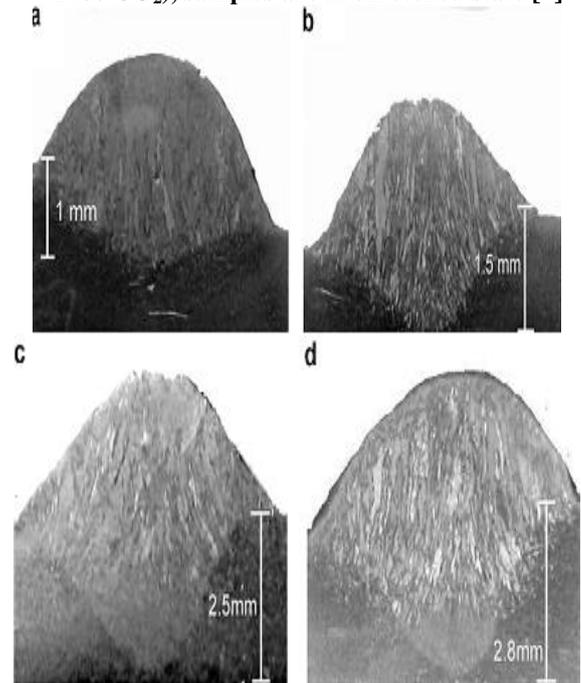


Fig. 8. Cross-section of weld pool samples. (a) S1 (97.5% Ar + 2.5% CO_2), (b) S2 (90% Ar + 10% CO_2), (c) S3 (82% Ar + 18% CO_2), and (d) S4 (75% Ar + 25% CO_2). [7]

And finally they summarized that on increasing the amount of carbon dioxide leads to decrease in the amount of inclusion and porosity and the volume fraction of acicular ferrite decreases and the volume Fraction of Widmanstatten ferrite increases in microstructure with increase of the amount of carbon dioxide. Charpy V-notch energy first increases and then remains constant with increase of the amount of carbon dioxide in the shielding gas and Weld metal hardness decreases due to increase of the amount of CO_2 in the shielding gas composition.

S. Mukho padhyay and T.K. Pal [8] In this work, gas metal arc welding of high strength low alloy (HSLA) steel with solid and flux-cored arc welding wires using different shielding gas compositions was performed. The composition of filler wire and shielding gas in gas metal arc welds of HSLA steel determines the inclusion characteristics, microstructure and mechanical properties. Thus, acceptable weld metal properties in HSLA steel using gas metal arc welding (GMAW) process could be achieved with the proper combination of filler wire and shielding gas composition. High strength-low alloy (HSLA) steel of 700 MPa minimum yield strength was used as a base material. Solid wire (ER 70S6) and flux-cored wires (E 71T-

1M) of 1.2 mm diameter were used to weld the test plates. The nominal composition of the base and filler materials are given in Table 1. For solid wire, the composition of the shielding gas is 80% Ar + 18% CO₂ + 2% O₂ (S1), 80% Ar + 17% CO₂ + 3% O₂ (S2), 80% Ar + 16% CO₂ + 4% O₂ (S3), and 80% Ar + 15% CO₂ + 5% O₂ (S4). For flux-cored wire, the composition of the shielding gas is 80% Ar + 18% CO₂ + 2% O₂ (F1), 80% Ar + 16% CO₂ + 4% O₂ (F2), and 75% Ar + 25% CO₂ (F3). Plates of 20 mm(*t*)×150 mm(*w*)×300 mm(*l*) with a single V-groove (60°) were used, and multi pass welding was carried out in flat position maintaining an inter pass temperature of 150 °C

Table 2. Welding parameters and shielding gas

Sample No.	Gas composition (Ar-CO ₂ -O ₂)	Pass sequence	Current (A)	Voltage (V)	Speed (cm/min)
S1	80-18-2	Root	214	32	28
		Top	270	33	28
		Back	205	32	28
S2	80-17-3	Root	213	32	28
		Top	271	33	28
		Back	205	32	28
S3	80-16-4	Root	215	32	28
		Top	270	33	28
		Back	204	32	28
S4	80-15-5	Root	214	32	28
		Top	270	33	28
		Back	204	32	28
F1	80-18-2	Root	234	32	27
		Top	282	35	27
		Back	222	32	27
F2	80-18-4	Root	235	32	27
		Top	281	35	27
		Back	222	32	27
F3	75-25-0	Root	233	32	27
		Top	280	35	27
		Back	225	32	27

Mechanical properties: The influence of shielding gas mixture on the tensile properties of the welds for solid and flux-cored wires is shown in Table 4. In case of solid wire, yield strength (YS) of the weld metal progressively increased with increasing oxygen content (up to 5%) in the shielding gas. On the other hand, Ultimate Tensile Strength (UTS) increased with increasing oxygen content up to 4%, and then decreased with further increasing oxygen content. The elongation appeared to be more or less same up to 4% oxygen content, and then drops. In case of flux-cored wire, both YS and UTS decreased with increasing oxygen from 2% to 4%. However, elongation remains more or less same. In shielding gas containing Ar+25% CO₂, YS remains the same but UTS and elongation both decreased. The Charpy impact values of weld metal both at 27 °C and at -30 °C indicate that maximum toughness was obtained at 4% oxygen addition in shielding gas for solid wire and 2% oxygen addition for flux-cored wire.

And they declared that The microstructural constituents such as AF, GF and FS in HSLA weld metals are influenced by the oxygen and carbon dioxide content in the shielding gas and In the case of solid wire welds, both YS and UTS increased with increasing oxygen content (up to 4%) in the shielding gas. Further increase in oxygen content resulted in reduction in UTS and % elongation of the weld metal. Gas metal arc welding can achieve acceptable weld metal properties in HSLA steel with the proper combination of filler wire and shielding gas composition. P. Sathiya and et al [9] investigates the bead geometry, microstructure and mechanical properties of AISI 904 L super austenitic stainless steel joint by CO₂ laser-GMAW hybrid welding process.

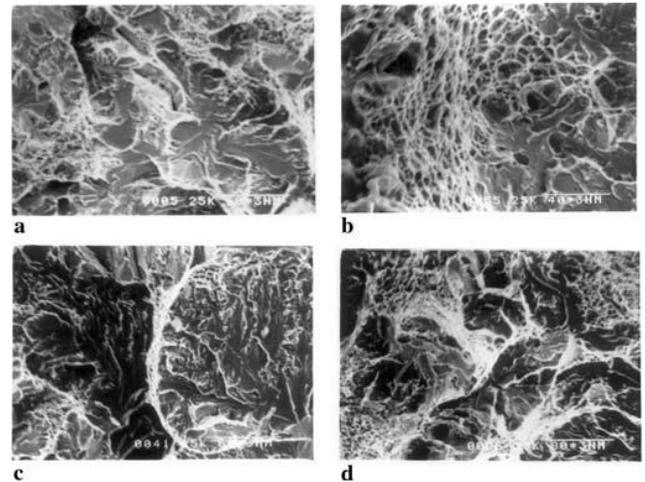


Fig 9. a–d. Scanning electron microphotographs of the fracture surface: a sample S1, b sample S3, c sample S4, d sample F1

Shielding gas is one of the important parameters for the process stability and efficient synergetic effects between laser and gas metal arc welding (GMAW). A detailed study of CO₂ laser-GMAW hybrid welding with different shielding gas mixtures in different ratio (50% He + 50% Ar, 50% He + 45% Ar + 5% O₂, and 45% He + 45% Ar + 10% N₂) was carried out on AISI 904 L super austenitic stainless steel sheet of 5 mm thickness Fig.10 to 12.

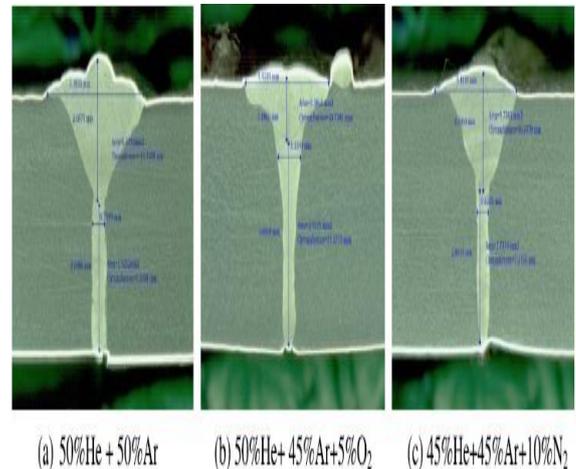


Fig 10. Micrograph of Hybrid Welded Joint [9].

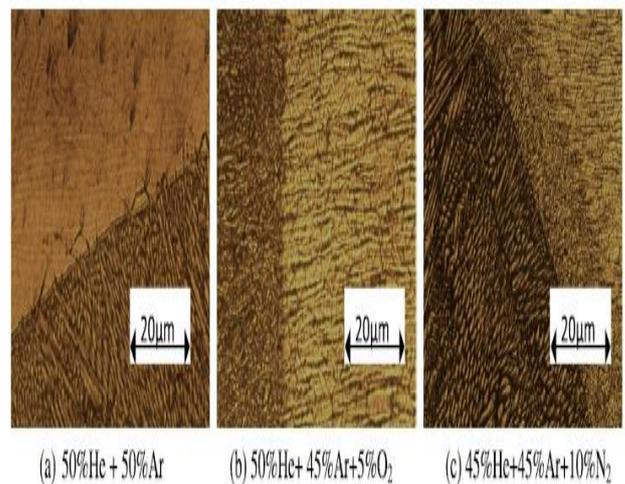


Fig 11. Weld junction micrograph [9]

Table 3. Tensile Test Result

Sl. no.	Shielding gas	Yield strength (MPa)	Ultimate tensile strength (MPa)	% of elongation	Fracture location
1	50%He + 50%Ar	470	579	40.0	Base metal
2	50%He + 45%Ar + 5%O ₂	491	594	48.3	Base metal
3	45%He + 45%Ar + 10%N ₂	479	585	46.8	Base metal
	Base metal	340	570	38.0	

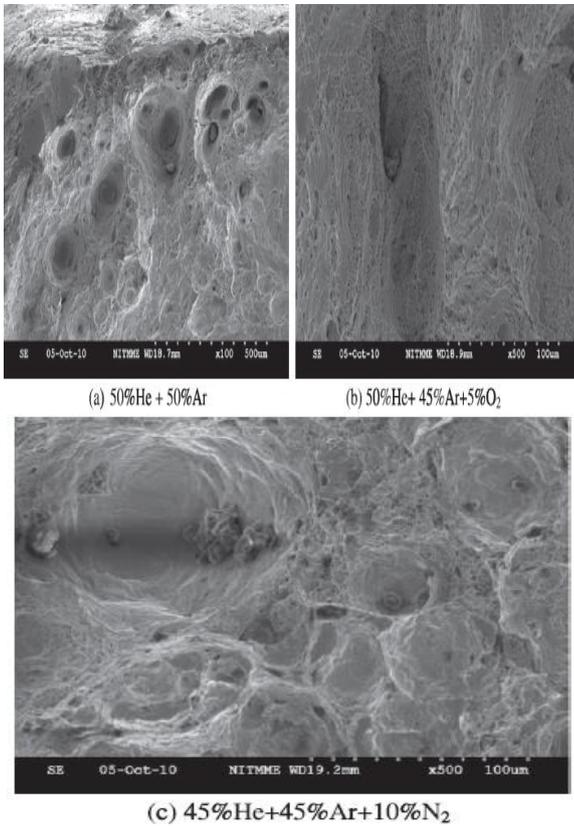


Fig 12. SEM fractograph of microstructure [9]

And finally they deduced that 1. The full penetration is achieved without any defects. The weld Shape is shallow and wide under 50% He + 50% Ar shielding gas mixtures. When a small amount of oxygen (5%) and nitrogen (10%) is mixed into the 50%He + 45%Ar and 45%He + 45% Ar shielding gas mixtures, the weld shape changes from the shallow type to the deep narrow shape. 2. Due to rapid cooling with high heat energy in laser zone, the grains are getting finer refinement. The laser (lower) weld zone microstructure had finer grains with equi axed grains are present. A higher percentage of long columnar grains are present in upper zone (GMAW). 3. In GMAW upper zone, 50%He + 45%Ar + 5%O₂ shielded weld metal has more primary dendritic and in the lower zone (laser) weld metal a high amount of primary dendritic is present in 45%He + 45%Ar + 10%N₂ shielding gas. 4. The 50%He + 45%Ar + 5%O₂ hardness values are higher than the other two shielded weld metal hardness in GMAW (upper) weld zone. Due to plasma plume suppression in addition of nitrogen shielding gas, the hardness values are higher in 45%He + 45%Ar + 10%N₂ shielded laser zone. 5. The tensile strength is less in 50% He + 50% Ar shielded weld when compared to other two shielded weld tensile strength. The fracture surface appeared in pure shear fracture in 45%He + 45%Ar + 10%N₂ and in 50%He + 45%Ar + 5%O₂ shielded fracture surface appears ductile with partially cleavage fracture Occurring. 6. 50%He + 45%Ar + 5%O₂ shielded weld joints exhibit higher impact toughness values, and the enhancement in toughness value is approximately 36% compared to base metal. The impact specimen fracture surfaces of the different shielding

gas laser–GMAW hybrid welded joints show mixed mode fractures, that is, ductile and cleavage fractures.

X. LI and et al [10] studied the effects of oxygen contamination in the argon shielding gases on weld microstructures and properties during laser welding of commercially pure titanium thin Sheets. The experimental results, mainly analyzed by optical and scanning electron microscopy and mechanical testing, have indicated correlations between weld surface colour, weld microstructure and mechanical properties (strength, ductility, hardness). As the oxygen content increased, the weld surface colour changed from silver, straw to blue while the surface hardness continued to increase. On the other hand, with the increasing of oxygen content, the weld strength increased first and then decreased because the microstructure changed from mainly serrated alpha in welds made with pure argon shielding gas to mainly acicular and platelet alpha. Fig.13.

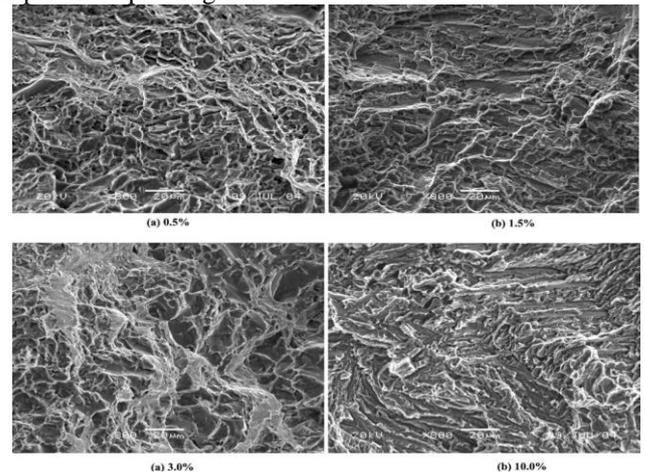


Figure 13. Fracture surfaces of welds made with various oxygen content in argon shielding gas [10]

Behçet Gülenç and et al [11] welded 304L stainless steel was bonded by MIG welding and mechanical and microstructural properties of the welded samples were investigated. Welding was carried out under different shielding media, which are argon and different additions of hydrogen in Ar. As current values, 140, 180 and 240A were chosen for the welding current parameters. The sample that was welded under 1.5% H₂–Ar shielding media and with a welding current of 240A was found to be the best in terms of means of tensile strength. Impact tests revealed that toughness of the welding increases with increasing hydrogen amount in Ar and Welding current. For all the welding parameters, hardness test results showed that base metal gave a higher hardness value than HAZ and weld metal. Welded samples were also characterized by means of bending test and microscopic invest.

Table 4. Tensile strength and impact strength

Shielding gas	Current value (A)	Max tensile strength (N/mm ²)	% Elongation (mm)	V Notch strength (Joule)
Pure argon	140	580	39	115
	180	600	40	121
	240	610	40	125
HYLITE	140	610	40	128
	180	610	40	132
	240	630	42	134
HYPLAS	140	590	40	130
	180	610	43	134
	240	610	45	139

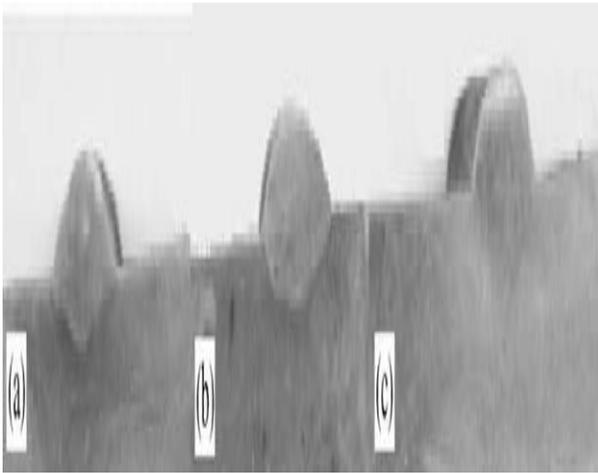


Fig 14. Macrostructure of penetration profiles bonding welded at 180A under different shielding: (a) pure Ar, (b) 1.5% H₂-Ar and (c) 5% H₂-Ar (x1). [11]

And finally they told that highest tensile strength was obtained from the welding that was carried out under 1.5% H₂-Ar shielding with a welding current of 240A and best toughness value can be obtained from the samples that were welded under 5% H₂-Ar shielding with a welding current of 240A. Increasing hydrogen content in argon as a shielding medium increased the penetration profile depth and width. Fig.14.

P. Kah & J. Martikainen [12] told that Shielding gases are of considerable significance in the protection of molten metal from atmospheric contamination during welding processes. These gases play an important role in a number of aspects of welding, including arc characteristics and the microstructure of weldments. Understanding of the influence of welding shielding gases on Different materials are consequently important, and extensive studies and experiments have been performed by numerous researchers. Based on previous studies, the objective of the current study is to collate and summarize the most important findings and approaches of earlier research

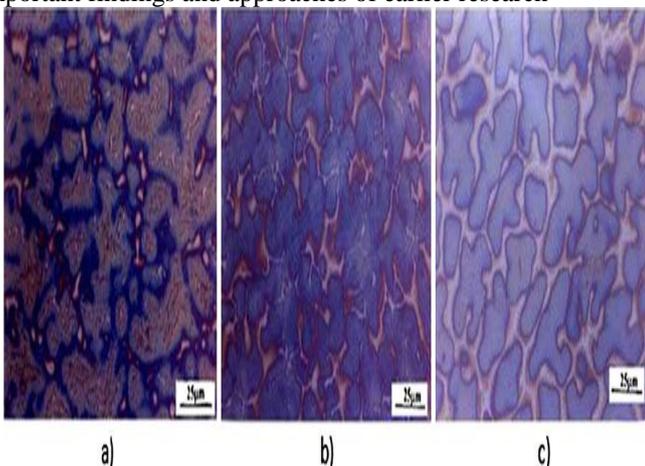


Fig 15. Optical micrographs of 317 L welds prepared with a 0 vol% N₂, showing vermicular delta ferrite in the dark austenite dendrites, b 0.5 vol% N₂ and c 1 vol% N₂ in the Ar shielding gas. The apparent interdendritic networks of micrographs b and c are due to secondary austenite [12].

And they told that austenitic stainless steel, increasing the amount of nitrogen in the shielding gas increases the ductility and improves the tensile strength, hardness and pitting corrosion resistance of the weld and for carbon steel, shielding blends of argon and CO₂ are very common. Increasing CO₂ in the mixture to 5–20 % can yield higher welding speed, greater penetration, less porosity and lower welding cost. For aluminium and its alloys, increasing the helium content of the shielding atmosphere

results in an increase in the impact energy and crack growth energy, And a decrease in the crack growth rate. Fig.15-17.

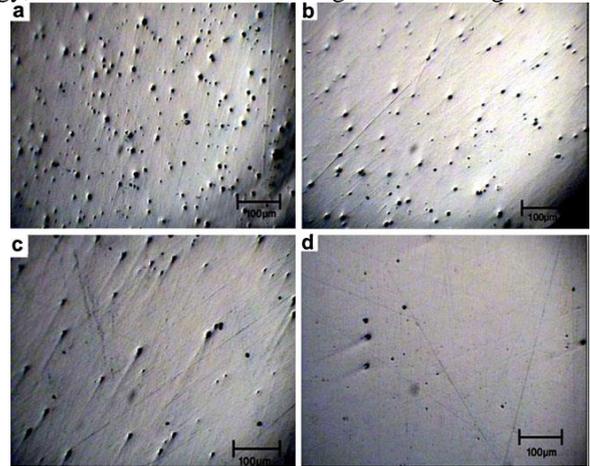


Fig 16. Inclusion in samples with different shielding gas composition a 97.5 % Ar+2.5 % CO₂, b 90 % Ar+10 % CO₂, c 82 % Ar+18 % CO₂ and d 75 % Ar+25 % CO₂. Samples are in unetched state. Material ST37-2. Process GMAW [12]

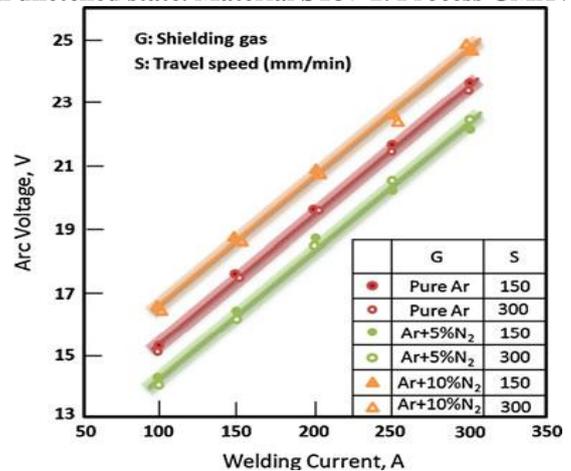


Fig 17. Relationship between arc voltage-current percentage of nitrogen gas added to an argon shielding gas, type 304stainless steel [12]

Conclusion

The main goal of the research paper is to review recent progress in using different shielding gases during the GTA & GMA Welding process. Different shielding gases and their mixture can be used to protect the molten metal from atmospheric contamination. For Al on increasing the He contents, impact strength of weldment increases.

Pure Argon & Helium are very costly shielding gases. If they used as shielding gases weld bead is good but costly, hence mixture of gases are used like, shielding gas using Ar + 1% O₂ or Ar + 5% H₂ can significantly promote the depth/width ratio. In general Helium content gases are used in GMAW/MIG welding process. Helium has a lower density than Argon .The weld Shape is shallow and wide under 50% He + 50% Ar shielding gas mixtures. Conclusion of this review paper is that shielding gases can not be directly used in welding some other gases mixtures are also required to get the required mechanical & microstructure properties of weldments.

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