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Effect of Different Purging Gases on Weld Geometry and Mechanical Properties of 304L Stainless Steel Using GTAW Technique

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Abstract:
Stainless steel is used in many applications due to its resistance to corrosion. When welding austenitic stainless steel, the weld seam is exposed to heat and air, which causes oxidation. Purging is an important step to obtain high quality and prevent oxidation and thus avoiding discoloration and welding under bead discontinuities. The right purging gas is essential for getting the best results. The purpose of this study is to determine how different purging gases, such as pure nitrogen, pure argon, and a mixture of 26% N2, 4% Co2, and 70% He, affect the mechanical properties of 304 L austenitic stainless steel welds, including their tensile strength, yield strength, and hardness. The results of this study show that as no significant differences in properties have been found, it may be concluded that all named gases can be used as purging gases in the welding of austenitic stainless steels.

Keywords: Shielding Gases, Purging Gas, Mechanical Properties, Austenitic, Microstructure

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1. Introduction

Austenitic stainless steels are the first choice for many engineering applications due to their improved mechanical properties and excellent corrosion resistance. These features make austenitic stainless steels desirable in the pressure vessels, chemical industry, and petroleum industry. [1] One of the most significant arc welding processes is gas tungsten arc welding (GTAW), which shields the arc by using an inert gas and a non-consumable tungsten electrode. A blanket of inert gas produced via the GTAW torch covers the heat-affected zone, the molten metal, and the tungsten electrode to protect them from ambient contamination. Welding should be done from the outside and the backing gas protects the underside of the weld and adjacent base metal surfaces from atmospheric contamination which may result in weld porosity or poor surface appearance. Regardless of the welding procedure utilized, the back purging should be maintained during multiple further layers of welding, and the needed gas flow rate is consequently considerable. [2] Generally, argon is used as a purge gas. The operational economy of producing austenitic stainless steel tube might be greatly increased if nitrogen could be used in place of argon and the cost of the two gases was significantly different. In helium gas, there was a deeper penetration and a shallower metal deposition. On the test specimen made of helium gas, the tensile strength was measured. In an Argon gas specimen, a high residual stress was recorded. The specimen made by argon gas has a rather high average hardness value.

According to the microstructure investigation, all specimens' weld metals had tempered martensite structures. Alongside the primary austenite and martensitic lath grain boundaries, the particles were seen in all specimens. According to the findings, specimens made of pure helium demonstrated higher weld qualities than those made of other gas compositions. [3] For 23 mm thick 22Cr duplex pipes manually welded with ER2209 filler metal using the GTAW technique, the impact of different levels of argon and nitrogen as backing gas on mechanical properties and corrosion resistance has been examined. The transverse tensile and hardness parameters of the root weld were unaffected by nitrogen. The composition of the backing gas could not be connected with impact toughness at -46°C, but at -65°C nitrogen had a substantial positive effect with smaller standard deviation. [4] The same behaviour was essentially displayed when Ar+2% N_2 was used as backup gas. When pure argon was applied as the backing gas, adding nitrogen to the shielding gas had no effect on the root-side's resistance to pitting. Pitting mostly occurred in the parent material, 1-3 mm from the fusion line where the heat tint is most visible before pickling, when 100% N_2 was used as the backing gas. The weld metal corrosion resistance significantly improved with 90% N_2+10% H_2. The GMAW samples that were welded using backing gas consisting of 90% N_2 and 10% H_2 showed the same improvement. In practice, only the backing gas containing hydrogen demonstrated the ASTM G150 standard's essential limit for acceptable corrosion tests. [4] With the assistance of this investigation, it was found that a good level of discolouration is obtained at an atmospheric oxygen content of less than 50 ppm, and a proper level is obtained at an atmospheric oxygen content of 10 ppm. Also, when the ambient oxygen content is above 100 ppm, the specimens break in the weld seam, as compared to when it is less than 100 ppm, whenever the tensile break will occur in the base metal. The resistance tests demonstrate that the fracture occurs in the base metal for welds with the presence of oxygen of 50 ppm, 25 ppm and 10 ppm; while in the rest it breaks in the weld bead. With the help of this investigation, it was found that attaining an appropriate level of discolouration when the ambient oxygen is less than 50 ppm and a good level when the atmospheric Morphological analyses have revealed that a welded joint with just 10 ppm of atmospheric oxygen inside the purge with argon prevents breakage in the weld seam and provides better mechanical resistance than AISI 304 steels that are employed by the industrial. [5] As a result of all the experiments and analyses, it is possible to claim that nitrogen is a suitable purging gas when welding austenitic unalloyed stainless steels because there is no significant different between both the properties of the nitrogen- and argon-purged joints. [6]

It could be concluded that nitrogen can be utilized as a purging gas in the welding of austenitic unalloyed stainless steels because the numerous tests and analyses reveal no comparable difference in the properties of the nitrogen and argon purged joints.

2. Experimental

Material and Welding.

304L stainless steel with chemical composition shown in table 1, spectrometric analysis was used to obtain the composition.

Table 1. The chemical composition of the welded steel.

C%	Si%	Mn%	P%	S%	Cr%	Ni%	Mo%	Al%
0.042	0.904	1.51	0.031	0.004	17.386	8.001	0.148	0.009
Co%	**As%**	**Ti%**	**Ca%**	**Nb%**	**Fe%**	**V%**	**W%**	**Cu%**
0.129	0.014	0.012	0.003	0.007	71.252	0.053	0.041	0.428

The butt weld joints of the base metal plates were cut and prepared with dimensions of 200 * 200* 2 mm. GTA welding were used without gap with the filler metal SFA 5.9 ER 308L with 1.6 mm diameter. The Ampere range of (80-90) as peak current and velocity of approximately 71 mm/min with DC pulsating current, the wave cycle with 10 Hz was used with 50 % pulse on time with range of 40 to 45 Ampere base current electrode negative and argon gas utilized as a shielding at rate of 8 litres/min and the purged gas were applied in three different gases namely, pure argon, pure nitrogen and mixture of 4 % Co_2, 26 % N_2 and 70 % He, at rate of 4 litres/min. Three butt joints were performed for each type of purged gas with the seam parameters. A certified inspector visually evaluated the quality of the welded joints.

Table 2. The chemical composition of ER 308L.

C%	Cr%	Ni%	Mo%	Mn%	Si%	N%	Cu%	Cr_{eq}/Ni_{eq}
0.02	19.62	9.56	0.08	1.84	0.34	0.038	0.16	1.781

Results and Discussion

Hardness Test

The samples of austenitic stainless steel 304L welded with the filler metal SFA 5.9 ER 308L and purged gases of pure argon, pure nitrogen and mixture of 4 % Co_2, 26 % N_2 and 70 % He were subjected to a Rockwell hardness (Ernst) machine to determine the difference in hardness including the weld metal, heat effected zone and base metal for all the joints. [7] Hardness value were found for each group are detailed in the table 3.

Table 3. The chemical composition of the welded steel.

Sample No	Purged gas	Current	Velocity Mm/min	BM hardness	HAZ hardness	WM hardness
W1	Ar	80-90	150	72	149	152
W2					120	160
W3					122	141
W4	N_2				109	128
W5					118	131
W6					141	150
W7	Mixture				139	154
W8					118	134
W9					124	127

Based on the result obtained from the hardness test, it could be concluded that pure argon, pure nitrogen and mixture of 4 % Co_2, 26 % N_2 and 70 % He can be utilized as a purging gas in the welding of austenitic stainless steels due to no comparable difference have been found.

Tensile testing

The purpose of the tensile test is to assess the influence of purging gases on tensile strength, yield strength, and the percentage of elongation of all welding joints. The test is done on Zwick Roell SP 1000 testing machine. The tensile specimens were prepared as shown in the Figure 1.

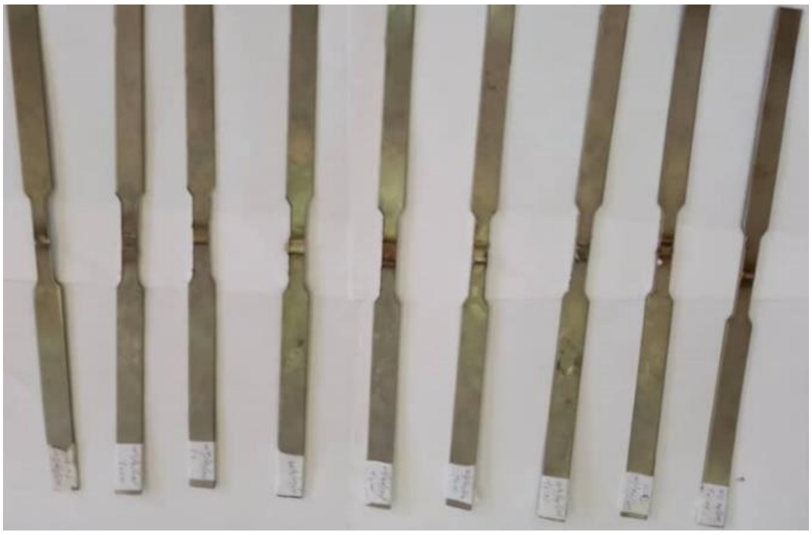

Figure 1. The tensile specimens

All of the tensile tests resulted in base material fractures and the ultimate tensile strength results show that there are no obvious variations in the tensile values as shown in the Figure 2, 3 and 4, which range from 641 N/mm^2 to roughly 657 N/mm^2 for all specimens with pure argon, pure nitrogen and mixture of 4 % Co_2, 26 % N_2 and 70 % He as purging gas.

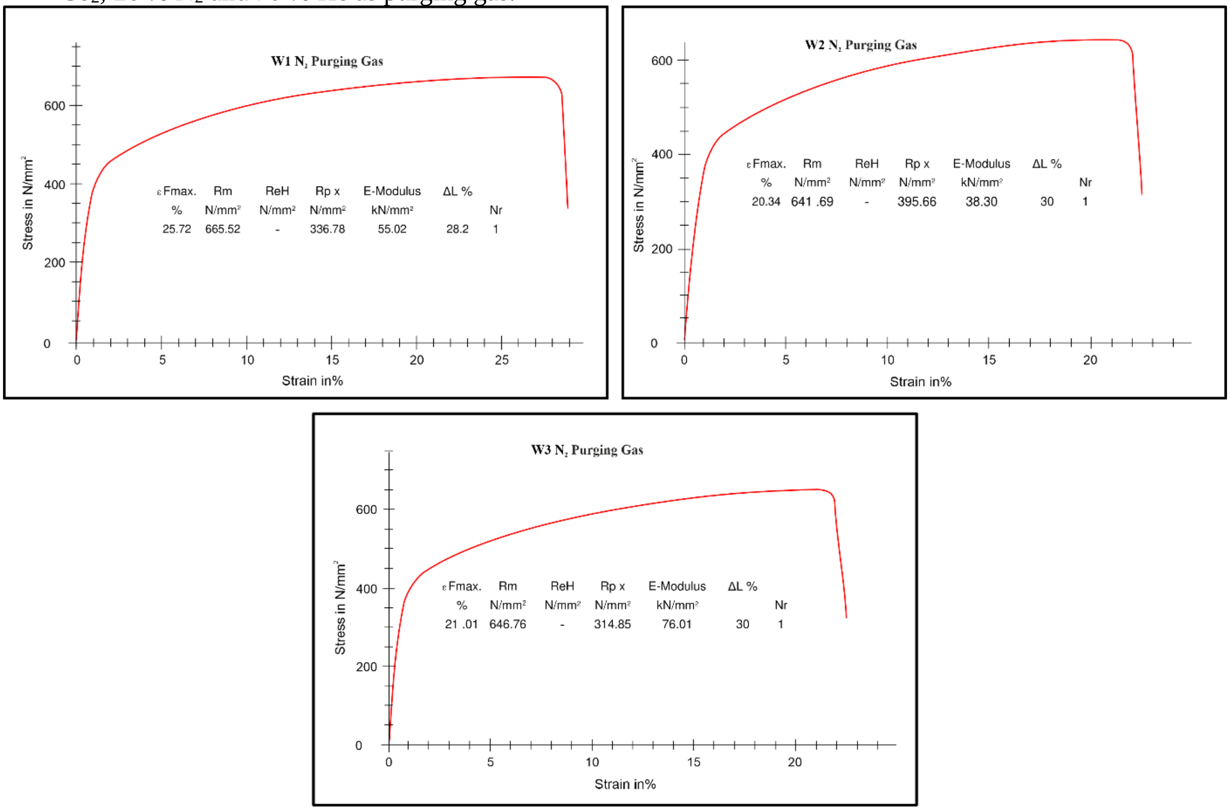

Figure 2. The tensile result with pure Nitrogen

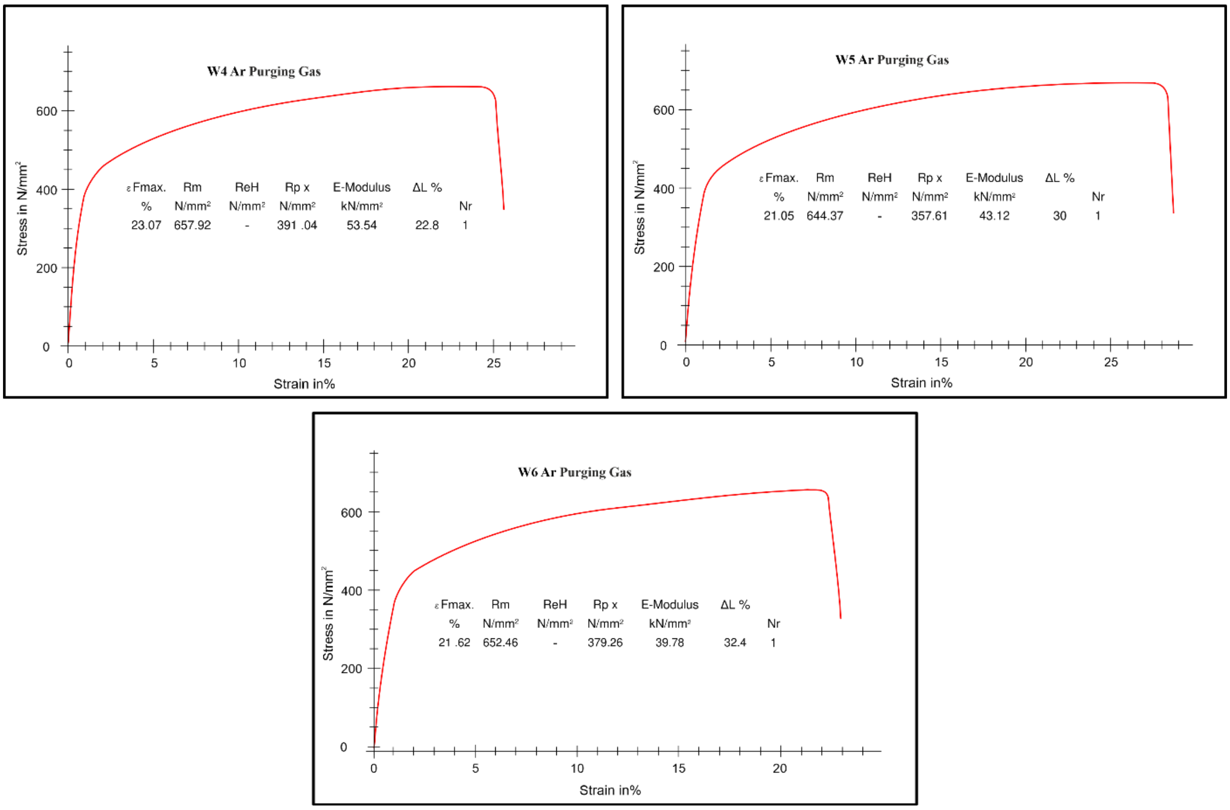

Figure 3. The tensile result with pure Argon

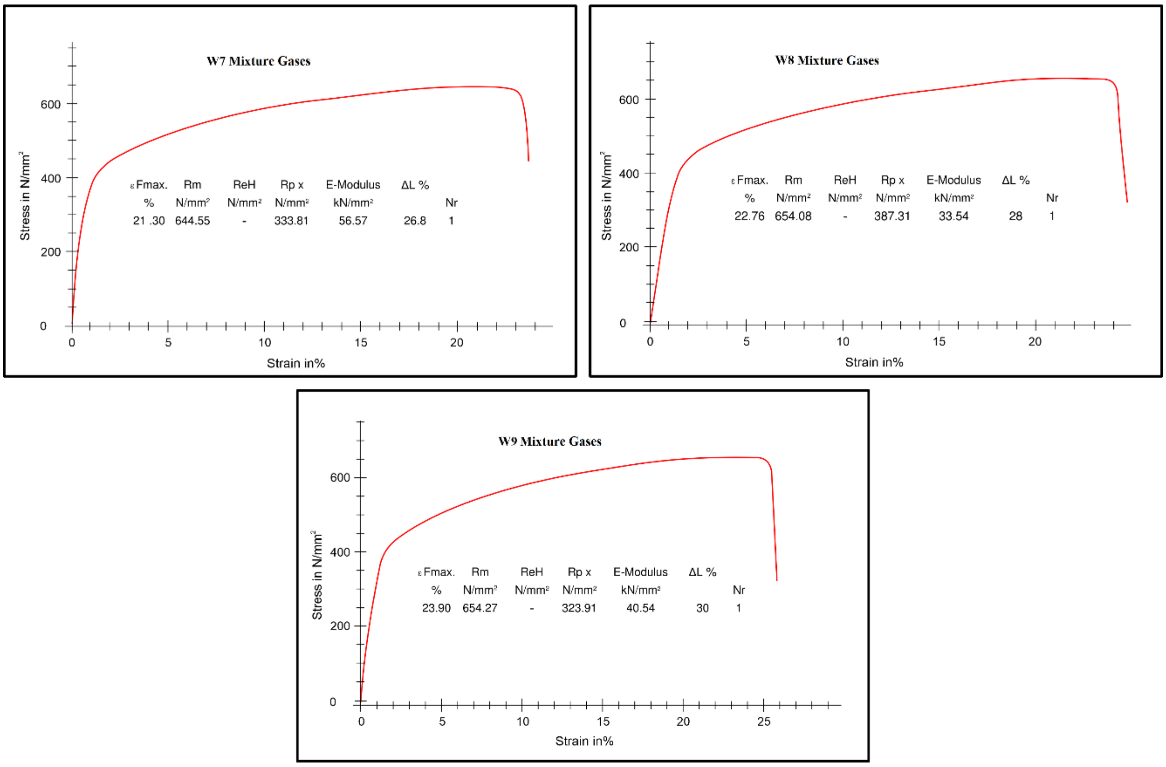

Figure 4. The tensile result with Mixture Gases

Metallographic

The figure 5 of base metal shows macrostructure of the substrate which is the rolled 304L stainless steel plate. Through the rolling method, the casting structure of the ingot is destroyed. The grains of the steel are refined and the defects of the microstructure are partially eliminated.

The figure 6, 7 and 8, shows the growth of the whole organization grows in a dendritic way. The macrostructure of the HAZ and WM samples is full of fine and messy dendrites. The reason why the dendrite orientation is complex and irregular is that the substrate temperature is relatively low and leads to the speeding up the cooling rate and producing more nucleation. This applies for all welded samples using pure argon, pure nitrogen, and a mixture of 26% N_2, 4% CO_2, and 70% He.

It should be noted that diffusion neglected amount of N_2 into the root and into the bulk could not affect the strength of final product.

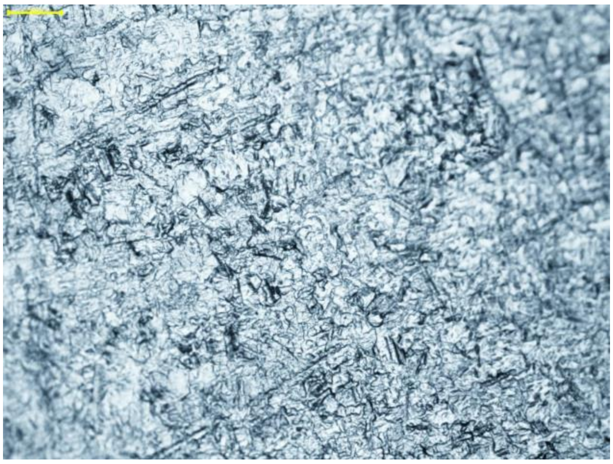

Figure 5. The macrostructure of base metal

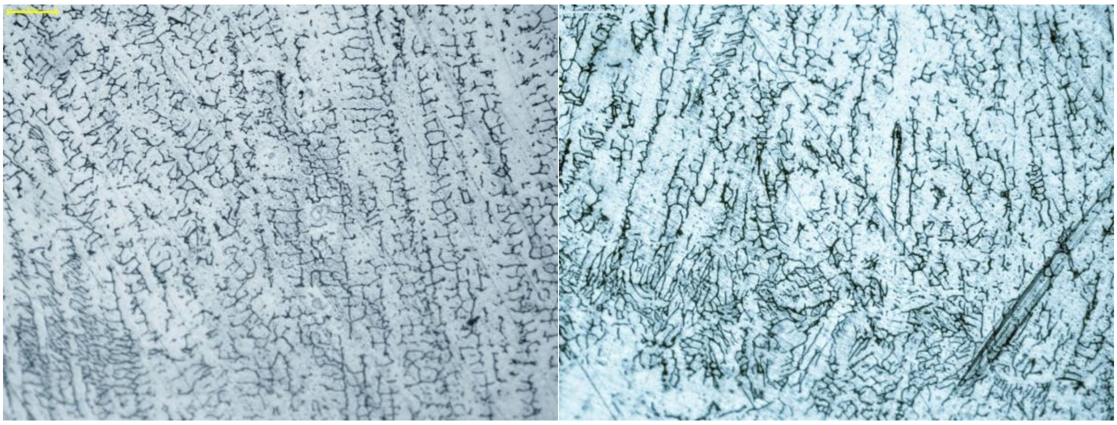

Figure 6. The macrostructure the HAZ and WM with pure Argon

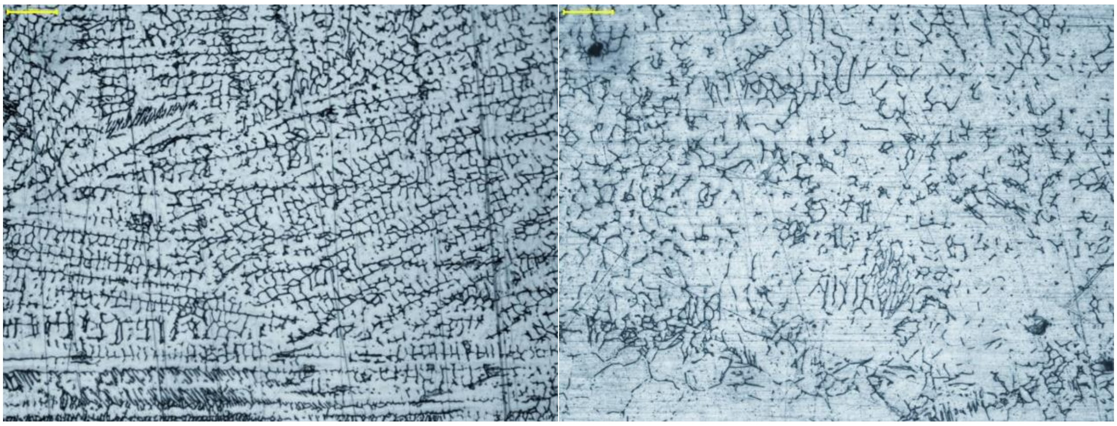

Figure 7. The macrostructure HAZ and WM with Mixture Gases

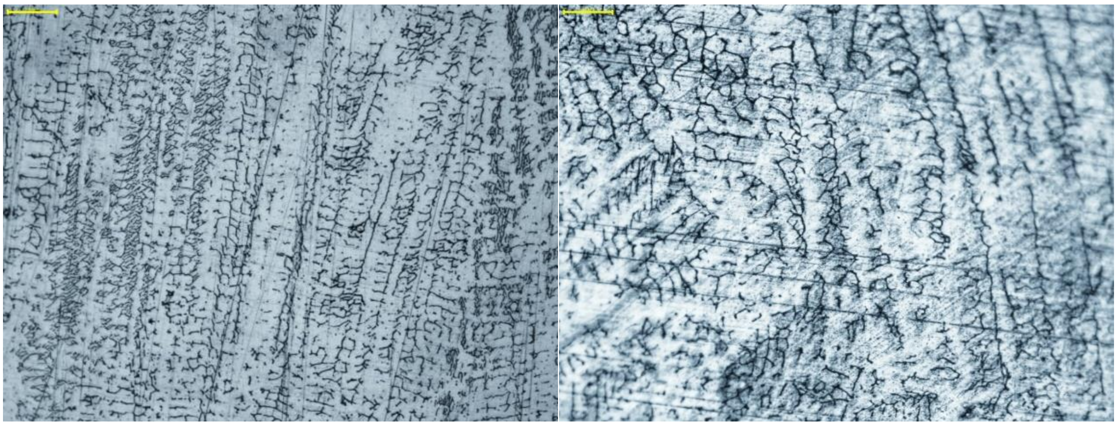

Figure 8. The macrostructure with HAZ and WM pure Nitrogen

CONCLUSION

304 L austenitic stainless-steel weld with a diameter of 1.6 mm SFA 5.9 ER 308L Filler Metal studied in relation to various purge gases, such as pure argon, pure nitrogen, and a mixture of 26% N_2, 4% CO_2, and 70% He on mechanical properties. Pulsing Peak currents in the (80-90 ampere range DC electrode negative and base current in the range of 40 to 45 Amperes with a welding velocity of roughly 71 mm/min are used. These parameters include a 10 Hz wave period and a 50% pulse time. Argon used as shielded gas at a rate of 8 litres per minute and an electrode negative. The results were analyzed and the following conclusions are distilled as follows and as shown in the figure 9:

- The purge gas had no noticeable effect on weld geometry and mechanical testing results.
- The findings of the metallographic examinations showed that the heat-affected zone and welded zone samples' macrostructures are a mass of fine dendrites.

- It should be highlighted that the strength of the finished product was unaffected by the neglected diffusion of N_2 into the root and into the bulk.
- As a result, nitrogen is typically its best choice and maybe more economical option for purging gas.

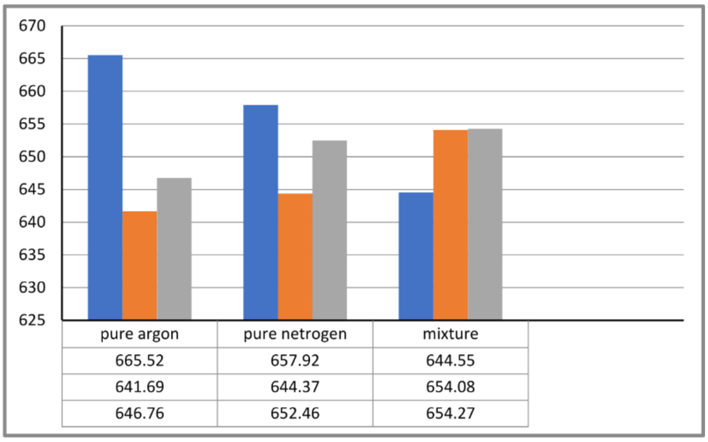

Figure 9. The teeth after hard facing

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