Purging with Nitrogen in the Welding of Austenitic Stainless Steels

Tests show no difference in properties between nitrogen and argon purged joints

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ABSTRACT. In welding stainless steel components such as pipes and tubes where the back of the joint is not accessible for welding by the GTAW or GMAW processes, the back is purged by argon gas. This purging may be maintained for more than one pass. The effect of replacing argon by nitrogen was investigated for the purpose of reducing welding costs. The study reveals that nitrogen can very well be used to replace argon for purging in pipe welding without any adverse effects on the properties of the unstabilized austenitic stainless steels.

Introduction

Austenitic stainless steel welding is widely performed in the fabrication of various components for the chemical, pharmaceutical, nuclear, food processing and other industries. In these areas, the welding of piping must be of a quality that will safeguard the full operating life of the plant and will avoid costly shutdowns for reasons of weld repairs.

The main processes used for welding of austenitic stainless steels are the gas tungsten-arc (GTA) and the gas metal-arc (GMA) welding processes for the thinner sections; for thicker sections, the welding procedure may include the submerged arc process as well as shielded metal-arc welding.

Back Purging

In all but very large diameter pipes, welding should be done from the outside only and the root passes are normally done by the GTA process. Gas backing is most frequently employed in conjunction with GTA welding. Backing gas protects the underside of the weld and the adjacent base metal surfaces from atmospheric contamination which may result in weld porosity or poor surface appearance. The requirement is for a small gas flow to maintain the purge. Where necessary to minimize oxidation on the inside surface of the pipe, the back purging should be maintained during several subsequent layers of welding regardless of welding process used. The volume of gas required is therefore considerable.

In India and elsewhere argon is commonly used as a purging gas. If nitrogen can be used to replace argon, there being a vast difference in the cost of the two gases, it can contribute substantially to the economy of the operation in the fabrication of austenitic stainless steel piping. Also nitrogen is used as an alloy in the development of high proof stress austenitic stainless steels. It is a potential austenitizer and thus reduces the delta ferrite content in the weld.

Taking note of these factors and the economic considerations, it was proposed to study the effect of nitrogen purging on a comparative basis to argon purging with respect to mechanical properties, weld structure and corrosion properties of welded joints in austenitic stainless AISI type 316 steel by the GTA welding process.

Experimentation

Butt welds were made with 4 mm thick AISI type 316 austenitic stainless steel plates using GTA welding. The root welds were made without any filler and the second pass of the two-pass butt welds was made with AISI type ER 316 L filler wire. The composition of the base plate and filler metal is given in Table 1. The welding conditions are given in Table 2. The weld root and adjacent plate showed no discoloration on the surface in both the argon and nitrogen purged joints.

Results and Discussion

1. Radiographic Tests. X-ray radiographs of the joints revealed the joints to be sound without any porosity and cracking both in argon as well as in nitrogen purged joints.

Table 1 — Composition of Base Metal and Filler Metal, %

	Cr	Ni	Mo	Si	Mn	C	N
Base Metal	16.65	11.45	2-3	0.3	1.61	0.09	0.14
Filler Metal	16.25	13.025	2-3	0.41	2 Max.	0.03 Max.	0.17

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Table 2 — Experimental Conditions

Sr. no.	Joint no.	Open cir. voltage, V	Arc voltage, V ± 1	Current, A	Welding speed mm/min	Heat input kJ/mm
1	1 N	63	10	66	25	1.584
2	2 N	62	10	85	34.3	1.4875
3	3 N	58.5	10	77	65	0.714
4	4 Ar	58.5	10	77	60	0.77
5	5 N	63	10	102	117	0.525
6	6 N	63	10	86	89	0.58
7	7 Ar	62.5	10	86	62.25	0.82
8	10 Ar	60	10	82	61	0.806
9	10 Ar	60	10	77	41.6	1.11
10	11 N	62	10	82	61	0.806
11	11 N	62	10	77	40	1.155
12	12 N	60	11	82	58	0.9325
13	12 N	60	11	77	45	1.131
14	13 Ar	60	11	82	44.5	1.23
15	13 Ar	60	11	77	38.8	1.31
16	14 N	60	11	83	46.8	1.157
17	15 N	60	11	82	40.75	1.33
18	16 N	62	11	84	18.35	3.02
19	16 N	62	11	82	20.10	2.69
20	17 Ar	56.5	11	130	166.4	0.515
21	18 N	56.5	11	130	144.3	0.594
22	19 N	62	11	120	162	0.489
23	20 Ar	61	11	120	133.5	0.593

Table 4 — Delta-Ferrite Content in the Weld

Sr. no.	Joint no.	Delta-Ferrite, % [a]
1	1 N	1 to 1.5
2	2 N	1 to 1.5
3	3 N	0.6 to 1
4	4 Ar	0 to 1
5	5 N	0 to 1
6	6 N	0 to 0.6
7	7 Ar	0 to 0.6
8	10 Ar root pass	0 to 0.6
9	10 Ar 2nd pass	Nil
10	11 N root pass	0 to 0.6
11	11 N 2nd pass	0 to 0.6
12	12 N root pass	0 to 0.6
13	12 N 2nd pass	Nil
14	13 Ar root pass	0 to 0.6
15	13 Ar 2nd pass	Nil
16	14 N	0 to 1
17	15 N	0 to 1
18	16 N root pass	0.9 to 1.5
19	16 N 2nd pass	0 to 0.6
20	17 Ar	0 to 1
21	18 N	0 to 1
22	19 N	0 to 1
23	20 Ar	0 to 1

(a) Estimated by observation of microstructure. In all cases, ferrite appeared to be more near the fusion boundary than at the center of the weld

Table 3 — Tensile Strength Results

Sr. no.	Joint no.	Proof stress kg/mm²	Tensile strength kg/mm²	Elongation, %	Remarks [b]
1	12 N [a]	38.3	60.075	52.125	FR
2	13 Ar [a]	39.55	61.05	49.4	FR
3	12 N	35.5	59.5	49.0	FB
4	13 Ar	33.3	58.6	47.5	FB
5	Base plate	33.7	59.1	54.0	—
6	Base plate	—	52.8	—	From standards

(a) Average of two close values
(b) FR = Failure in weld zone, reduced section test; FB = Failure in base plate

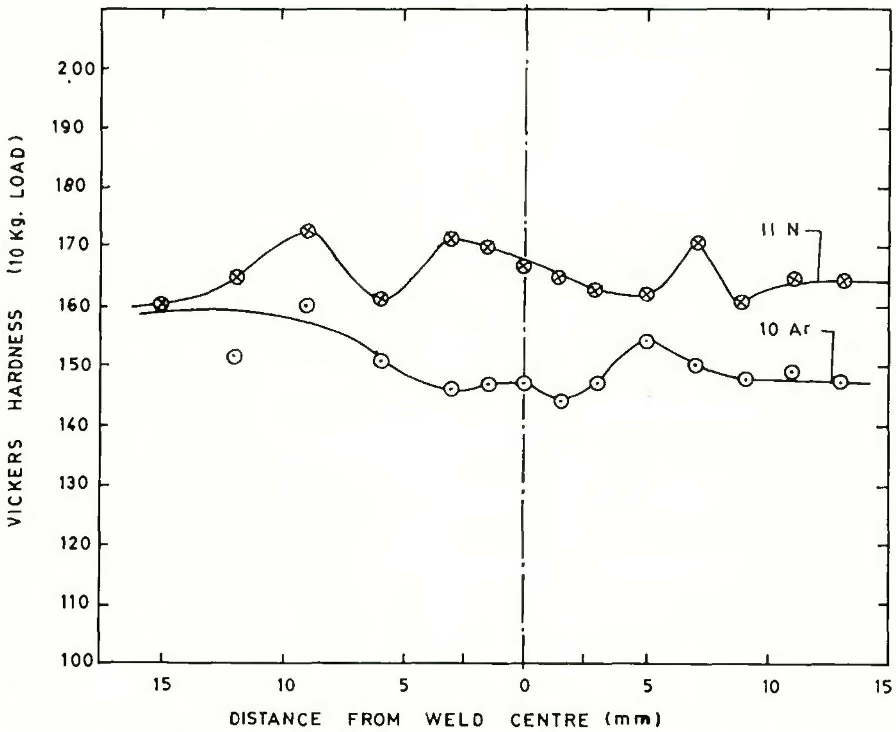

Fig. 1 — Hardness variation across the joint for nitrogen and argon purged welds

2. Mechanical Tests. The results of tensile strength tests along with percentage elongation are given in Table 3. Tensile strength tests revealed a weld proof strength of 38.3 kg/mm² and 39.55 kg/mm² in nitrogen and argon purged joints respectively and the base metal proof strength to be 33.7 kg/mm². The tensile strength was around 60 kg/mm² in all the three cases. The percentage elongation of the welded joints was found to be slightly less, i.e., 49 per cent and 47.5 per cent for nitrogen and argon purged joints respectively, than that of the base metal, which had a percentage elongation of 54 per cent. Guided 180 deg root bend tests showed no cracks on the root surface of both the argon and nitrogen purged joints.

The hardness variation curves of two argon and nitrogen purged joints as given in Fig. 1 show that the hardness variation is within 15 to 20 Vickers hardness number (at 10 kg load) across the joint including the weld portion, heat-affected zone (HAZ) and base metal in both the cases of purging. Similar results were found with all the argon and nitrogen purged joints.

3. Chemical Analysis for Nitrogen Content. The chemical analysis of the weld root portion for nitrogen content showed no pattern of variation of nitrogen content up to a root depth of 1 mm in either the nitrogen or argon purged welds as shown in Fig. 2(a) and (b). The results of average nitrogen content in the weld roots of argon and nitrogen purged joints with current are given in Fig. 3. It can be seen from Fig. 3 that the nitrogen content lies within the limit of 0.065 to 0.2

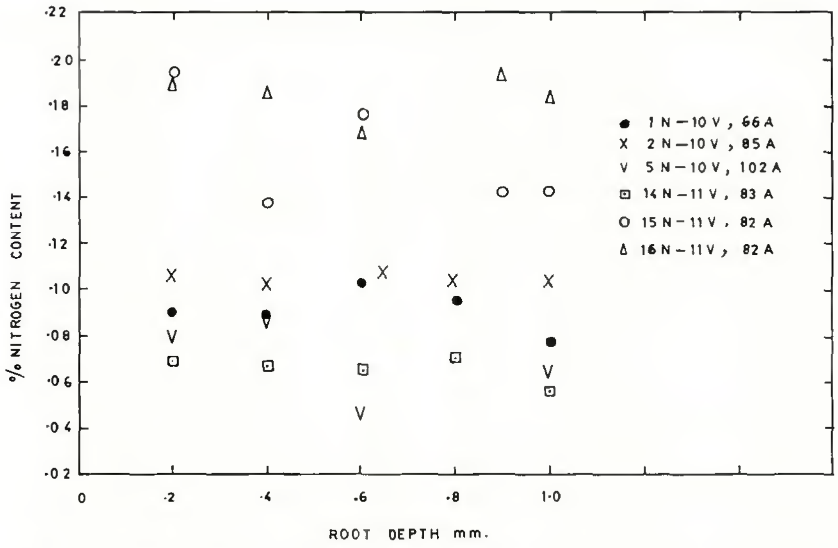

Fig. 2(a) — Nitrogen content variations in weld root passes for six nitrogen purged joints

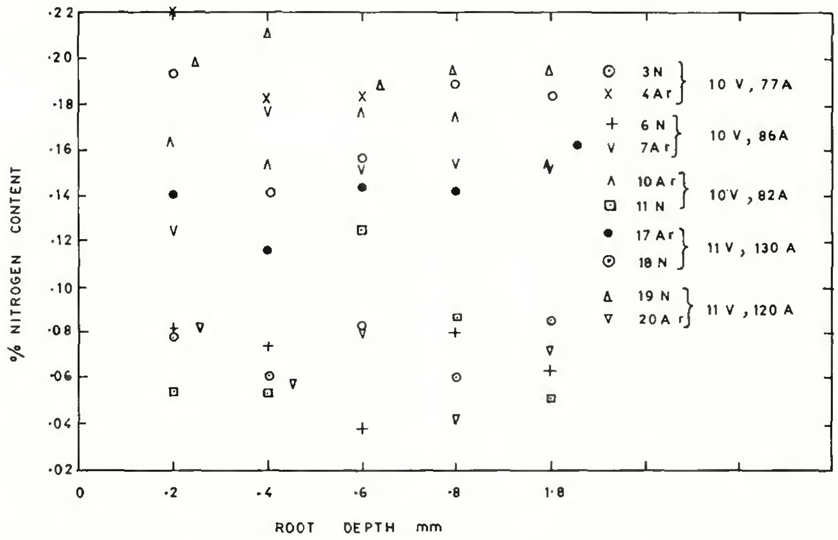

Fig. 2(b) — Comparison between nitrogen content variation in nitrogen and argon purged weld roots made with equal heat inputs

Table 5 — Carbide Precipitation

Sr. no.	Joint no.	Microstructural observations
1	1 N	Carbide precipitation in staggered regions along grain boundaries in a region 5 mm wide and about 5 mm away from the weld
2	2 N	
3	7 Ar	Slight carbide precipitation in staggered regions along grain boundaries in a region about 3 mm wide and about 5 mm away from the weld
4	10 Ar 11 N	Carbide precipitation in a region 5 mm wide and about 5 to 6 mm away from the weld. One or two grains completely surrounded by carbides
5	12 N 13 Ar 15 N	Carbide precipitation in a region 4 to 5 mm wide and 5 mm away from the weld. More than one grain completely surrounded by carbides
6	16 N	Carbide precipitation completely surroundig the grains in a region about 5 to 6 mm wide and about 3 mm away from the weld
7	14 N	Slight carbide precipitation in HAZ
8	Other joints	No carbide precipitation

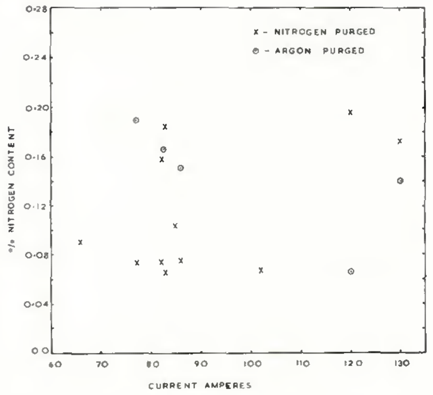

Fig. 3 — Average nitrogen content of weld root passes as a function of current

per cent irrespective of whether the joint is argon purged or nitrogen purged. The maximum nitrogen content is less than the equilibrium solubility of this element in these types of steels. The second pass of the two-pass joints showed a nitrogen content equal to that of the filler metal or slightly more.

4. *Microstructural Examination.* The delta-ferrite content estimates are given in Table 4. Delta-ferrite presence in all cases was found more near the fusion boundary than at the center of the weld. The estimates of delta-ferrite content in the joints were found to be below one per cent and in some cases below 0.6 per cent. In the second pass of two-pass joints, fully austenitic weld metal was found. Even with such low ferrite content, no microcracks were found in the joints.

Estimates of carbide precipitation are given in Table 5. The carbide precipitation was found to be varying depending on the specific heat input. It is observed from Table 5 that there is no carbide precipitation for specific heat energy inputs equal or below 0.8 kJ/mm run.

5. *Corrosion Resistance Test.* The "oxalic acid etch test," recommended by ASTM for classification of etch structures of stainless steels for screening specimens for acceptance in the total submersion corrosion tests, was used to study the nature and extent of corrosion of the nitrogen and argon purged joints. The results are given in Table 6. From the corrosion test results it can be seen that heat-affected zone was attacked in the cases where the specific heat input was above 0.8 kJ/mm run. The weld corrosion was of interdendritic "ditches" type in both the nitrogen and argon purged joints. There was no difference in the nature and extent of corrosion in the nitrogen and argon purged joints.

Conclusions

1. The various tests and analyses show no comparative difference in the

properties of the nitrogen and argon purged joints and hence it can be concluded that nitrogen can very well be used as a purging gas in the welding of austenitic unstabilized stainless steels.

2. Welding should be performed with the minimum specific heat input possible.

Table 6 — Corrosion Test Results

Sr. no.	Joint no.	Microstructural observations
1	1 N 2 N	Dual structure HAZ attack; grain boundaries partly surrounded by ditches, weld attack, interdendritic ditches
2	3 N, 17 Ar 4 Ar, 18 N 5 N, 19 N 6 N, 20 Ar	No HAZ attack; Weld attack by interdendritic ditches
3	7 Ar	Very slight HAZ attack; Weld attack by interdendritic ditches
4	10 Ar 11 N	HAZ attack, ditch structure, one or two grains completely surrounded by ditches, weld attack, interdendritic ditches, more in second pass
5	12 N 13 Ar	HAZ attack, ditch structure, more than one grain completely surrounded by ditches, weld attack, interdendritic ditches, more in second pass
6	14 N	HAZ attack feeble, dual structure, grains partly surrounded by ditches. Weld attack, interdendritic ditches
7	15 N	HAZ attack, ditch structure, more than one grain completely surrounded by ditches, weld attack, interdendritic ditches
8	16 N	Heavy HAZ attack, ditch structures, grains completely surrounded by ditches, weld attack, interdendritic ditches, more in second pass

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