Feasibility of Pressure Balanced Joint using Single wire GMAW and Tandem GMAW

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ABSTRACT
Currently, plastic lined pipes are used for water injection lines. The pipes are welded using the "weld link" method and are installed by the reeling method. However, for deep water, reeling method is not efficient and if using the "weld link" method for pipe line techniques the production time and installation cost will dramatically increase because there is a joint every 25m - 50m.The PBJ to allow shorter pipe sections to be joined at a faster rate and to reduce the installation cost. The results also revealed that both Single wire GMAW and Tandem GMAW can be used to weld the steel pipe incorporating the PBJ with Aero gel blanket of 2.5mm and 5.5mm nominal thickness without deforming the PBJ under the conditions used in the trials.

I LITERATURE REVIEW

(a) Introduction - Over the years, pipelines have been used as transportation systems, for transporting materials such as slurries, sewage, oil, refined products, gas and chemicals. The pipelines are made of materials such as composite, plastic, alloy steel, carbon steel, ductile iron, and concrete. [1]. currently, their consideration for use as hydrocarbon pipeline is gradually increasing because of the cost benefits involved. Plastic- lined pipes for WI lines have been installed by the reeling method. The reeling method is limited to smaller diameter pipes (16 inches diameter as upper limit). In deep water and sites distant from infrastructures, reeling installation of pipelines is inefficient and uneconomical. The increasing demand for plastic-lined pipelines with diameters greater than 18 inches, and the need to install the pipelines in deep water and long-distance, prompted companies to search for the most economic and efficient installation technique. To reduce the installation cost of plastic-lined pipeline, Boreas Consultants [5] developed and patented Pressure Balanced Joint (PBJ). This allowed shorter pipe sections to be joined at a faster and cheaper rate. The PBJ proved to be more cost effective than the weld link and also demonstrated its ability to maintain a stable corrosion barrier at the welded joints in plastic-lined pipelines. At present, the PBJ is targeted for WI lines.

(b) Swage lining Process - The swage lining process is the technology employed for the lining of existing pipe with tight fitting poly ethylene (PE) pipe. The swage lining die temporarily reduces the outer diameter of the PE pipe to allow the PE pipe to be pulled easily through the steel pipe. Upon removal of the pulling force, the plastic pipe relaxes and expands, pressing tightly against the internal surface of the steel pipe. The pipes are lined in length of 1650-ft using the swage lining process (see fig.1), and the weldlink fittings (see 4) are welded at the end of each stalk[4].

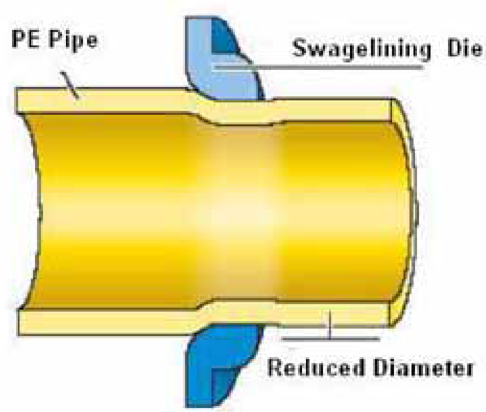

Fig No. 1 Swage lining Die

Fig No. 2 Reduced Plastic liner pulled from swaging block via a towing head about to go into the pipe

Fig No. 3: Plastic liner pulled through the steel pipe with the Weld link welded to the end of the stalk

Fig No. 4: End of a stalk with weld link assembly

(c) **Pressure Balanced Joint (PBJ) -** In 2003, Boreas developed and patented the PBJ for joining lined pipes for steel pipe welding methods. The development was as a result of the demand for a cost effective joining technique for plastic lined water injection lines for deep water projects. The PBJ (see Figure 5) is a short plastic pipe with a distinct profile machined on its exterior surface with a linavent inserted in the mid-length to facilitate pressure balancing between the bore and the annulus. Its essential purpose is to provide a corrosion barrier, deterring the flow of the fluid in the bore to the wall of the steel pipe at the welded join[7] t.

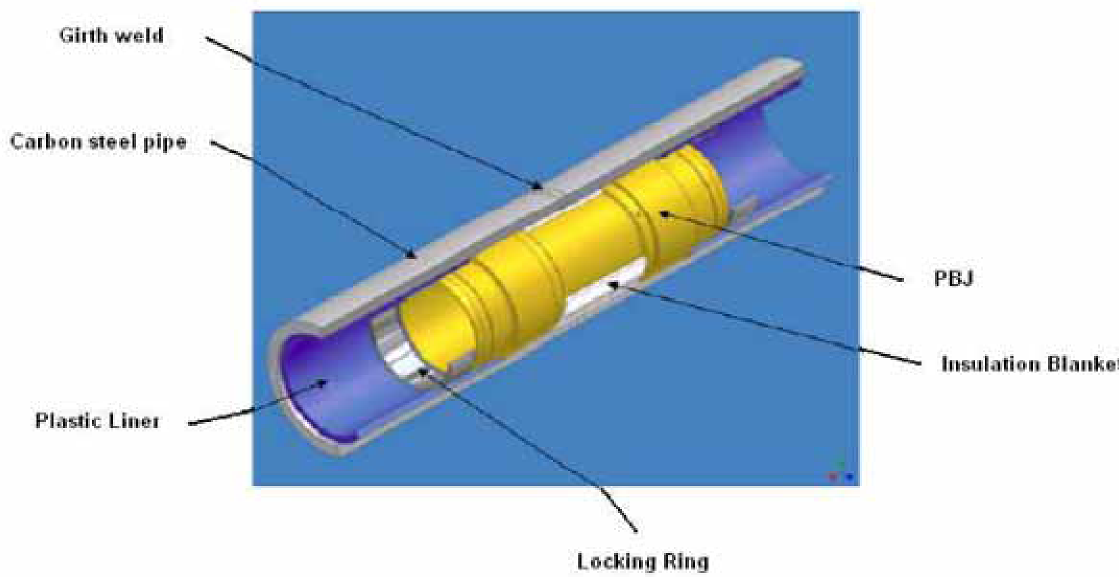

Fig No. 5: PBJ Assembly

(d) **Welding Processes for Pipelines.**

(i) **GMAW -** Gas Metal Arc Welding (GMAW), by definition, is an arc welding process which produces the coalescence of metals by heating them with an arc between a continuously fed filler metal electrode and the work. The process uses shielding from an externally supplied gas to protect the molten weld pool. The application of GMAW generally requires DC+ (reverse) polarity to the electrode .In non-standard terminology, GMAW is commonly known as MIG (Metal Inert Gas) welding and it is less commonly known as MAG (Metal Active Gas) welding .In either case, the GMAW process lends itself to weld a wide range of both solid carbon steel and tubular metal-cored electrodes. The alloy material range for GMAW includes: carbon steel, stainless steel, aluminum, magnesium, copper, nickel, silicon bronze and tubular metal-cored surfacing alloys[2] [3].

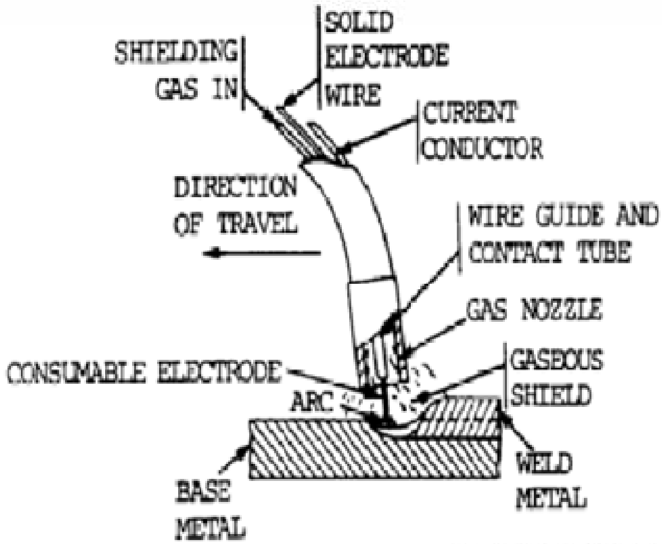

Fig No. 6: Gas metal arc welding process

(ii) **Single wire GMAW** - Initially, pipelines are welded using oxy-acetylene process in the early 1920's prior to the advent of the MMAW in the late 1920's In the 1940's, a continuously fed filler wire welding process, referred to as the GMAW (single wire GMAW) was introduced. It is normally operated on the DCEP mode due to improved arc stability. Currently, GMAW process is predominantly used for pipeline construction[4].

- **Advantages**
  - Reduced weld completion time.
  - Low cost of consumables.
  - Improved mechanical properties.
  - Low risk of slag inclusion.
  - Reduced pre heating.
  - Reduced skill requirements
  - Low risk of hydrogen induced cracking

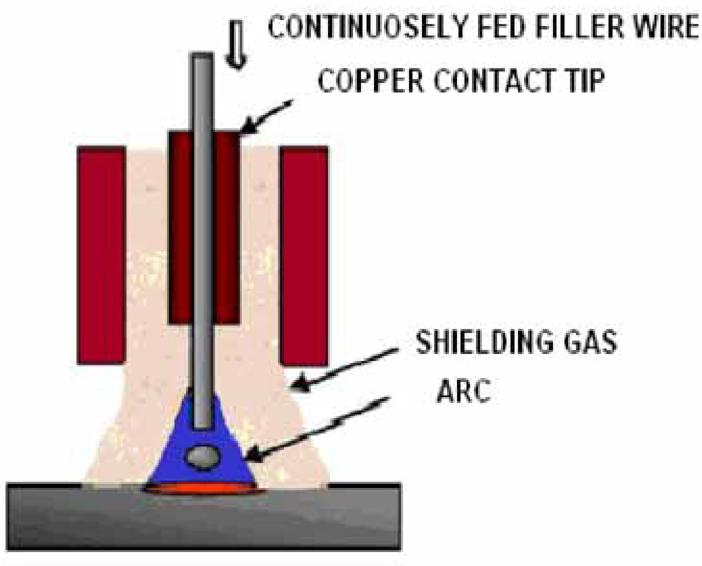

Fig No. 7: Principles of GMAW

Typical GMAW power sources have constant voltage output characteristics (see Fig.7) and normally produce direct current (DC) output. This allows the arc length to remain constant due to an electrical characteristic known as self-adjustment. If the arc length varies, an equivalent variation in arc current will take place such that the melting rate will change to resist any alteration of the original arc length. This provides improved process stability

The fundamental task of the GMAW torch is to guide the wire, shielding gas and current to the welding zone. They must be strong enough to bear the rough handling by the welder and also survive the high temperature of the arc. However, they must be flexible, weightless and comfortable for use[8].

(iii) Tandem GMAW In the mid 90's, the Tandem GMAW was introduced to further increase productivity, part throughput as well as reduced cost of pipeline construction. It is a twin wire that uses waveform control technology to synchronize two independently generated arcs (the lead arc and trail arc). The process utilizes two welding power sources and two wire feeders operating in tandem to deliver two filler wires via a single torch.

The welding arcs operate simultaneously in the same weld puddle, separated by not more than 0.5 inch. The thermal and fluid dynamics of the weld puddle are influenced by the independent control of the two welding arcs to help improve welding performance.

The Tandem GMAW offers high deposition rate, up to 24Kg/hr at a travel speed of 0.8m/min and travel speeds more than twice that of single wire GMAW (up to 5 m/min for a 2mm lap joint) [6] [10].

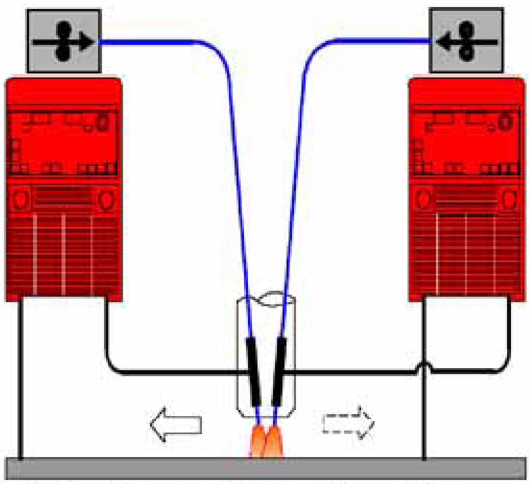

Fig No. 8: Tandem welding with two tubes electrically insulated from each other

Fig No. 9: Tandem Wire GMAW with two wires in the same

- **Advantages**
  - High welding speeds.
  - Faster cycle times.
  - Reduced heat input.
  - Resists burn-through on thin materials.
  - Low spatter levels.
  - Good penetration on thick materials.

- **Disadvantages**
  - Major disadvantage is cannot be used in the vertical or over head welding position due to high heat input.
  - The equipment is very complex.

III MATERIALS, EQUIPMENT AND EXPERIMENTAL TECHNIQUES

(a) Materials

(i) Pipe Materials - Pipes of grade X65 with 12 inches outside diameter and 22/24mm wall thickness were used for the trials. The pipes were received in 150mm long with J-bevel of angle 50 atone end of each pipe. Pipeline Technique Ltd prepared the bevels utilizing a pipe facing machine.

(ii) Pressure Balanced Joint - The PBJ is a HDPE machined out of a blue plastic pipe with specially machined profile. It incorporates a groove at the mid-length to accommodate the aerogel blanket. It has softening temperature of about 80 C.

Fig No. 10: Pipe storage.

Fig No. 11: PBJ

(iii) **Aerogel Insulation-** Aerogel insulation, a patent of Aspen Aerogels, Inc., is a nanotechnology- enabled product with high insulating properties. It a ready-to-use blanket infused with silica nanostructures that make it easy to conserve energy [9].

- **Feature**
  - Aero gel has excellent temperature resistance.
  - Light weight.
  - No requirement for vacuum sealing.
  - Easy of installation

Fig No. 12: Aerogel Blanket

(b) Equipment

(i) Power Source

The power source used is the Lincoln Electric power wave 455 STT with the specification:

- Welding current range : 5-500Amps
- Maximum OCV : 75Vdc
- Pulse frequency : 0.15- 1000Hz
- Pulse voltage range : 5- 55Vdc
- Pulse and background time range : 100μ sec. -3.3 sec.
- Input voltage : 400V ± 15%
- Input frequency : 50/60 Hz

The power source operates on the synergic and non-synergic welding modes. It allows the operator to set a required wire feed speed and the machine will select the correct current voltage and current.

The power wave is a semi-automatic, high performance, digitally controlled inverter welding power source capable of complex, high speed waveform control; designed to be a part of a modular, multi-process welding system. Depending on the configuration, it can support CC, CV, GMAW, PGMAW, FCAW, GTAW, CAC, pulse welding and STT mode.

Fig No. 13: Power Source

(ii) Welding Torch - The fronius tandem torch with dual wire was used. The two wires are contained in contact tubes which are electrically insulated from one another. They also run through a common gas nozzle which entails that the two wires must share common welding torch.

Fig No. 14: Tandem torch mounted on bug

(iii) Temperature Measurement - Temperature measurements at different positions were conducted using the K-type thermocouples (Chromel +ve - Alumel -ve). The thermocouples were situated at different positions on both the carbon steel pipe and on the PBJ. Eight K-type thermocouples were used.

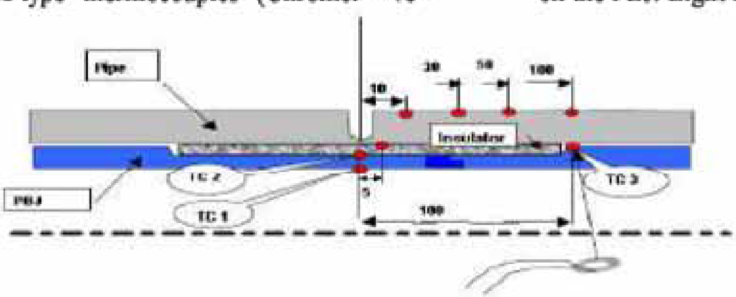

Fig No. 15: Locations of Thermocouples.

(iv) Temperature Measurement Equipment - The temperature readings were obtained from the K-type thermocouples using the National Instruments modules allowing 16 channel temperature measurements. One high accuracy isothermal block module (SCXI- 1328) accommodated up to 8 thermocouples, for 8 temperature measurement channels.

Fig No. 16: Temperature data capture monitor

(c) Experimental processure.

(i) Pipe Cleaning (Grinding and wire brushing)
(ii) Tack welding of two of the pipes using GMAW.
(iii) Placing the thermocouples on the pipe by capacitor discharge welding.
(iv) Placing the thermocouples on the PBJ with soldering iron by melting the plastic and plunging the thermocouple into the melted plastic.
(v) Wrapping the PBJ with the aerogel blanket.
(vi) Placing the pipe on the rotator.
(vii) Inserting the PBJ in the pipe.
(viii) Welding of the pipe.
(ix) Cutting of the specimen for macro structural examination.

Fig No. 17: Ground and wire brushed pipe

Fig No. 18: Aligned pipes with tack welds

Fig No. 19: Thermocouples located on the outer surface of pipe

Fig No. 20: Thermocouple located on the inner surface of pipe

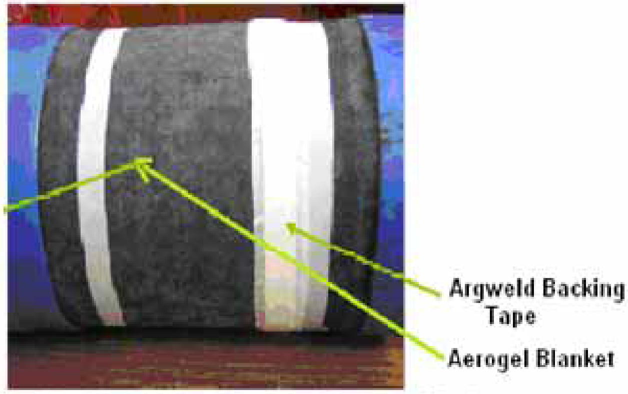

Fig No. 21: PBJ wrapped with aerogel before inserting it in the pipe

Fig No. 22: Thermocouples located on the outer surface of PBJ

Fig No. 23: PBJ inserted in the pipe

IV RESULTS & ANALYSIS

(a) Results

(i) Data for Single wire pipe weld with 2.5 mm nominal thickness of aerogel blanket- The arc on time measured was about 15 minutes and the total welding period measured was about 50 minutes. An average deposition rate of 2.04 kg/hr was calculated for the single wire MIG.

(ii) Data for tandem pipe weld Trials-The arc on time measured was about 15 minutes and the total welding period measured was about 50 minutes. An average deposition rate of 3.78 Kg/hr was calculated for the tandem MIG.

Table No. 4.1
Welding Parameters for Single wire Welding

WELDING PARAMETER							
DESCRIPTION TANDEM WIRE WELD		MATERIAL GEADE - X65 DIA - 18" WALL THICK - 22/24mm					
PASS	PROC-ESS	ELECTRODE				SHIELDING GAS	
		POLARITY	BRAND	BATCH	SIZE MIN	TYPE	FLOW L/MIN
ROOT	GMAW	DC +VE	LA 100	EDPN 9241	1.0	82.5%Ar/12.5%CO2 / 5 %He	25
HOT PASS	GMAW	DC +VE	LA 100	EDPN 9241	1.0	82.5%Ar/12.5%CO2 / 5%He	25
FILL 1	GMAW	DC +VE	LA 100	EDPN 9241	1.0	82.5%Ar/12.5%CO2 / 5%He	25
FILL 2	GMAW	DC +VE	LA 100	EDPN 9241	1.0	82.5%Ar/12.5%CO2 / 5%He	25
FILL 3	GMAW	DC +VE	LA 100	EDPN 9241	1.0	82.5%Ar/12.5%CO2 / 5%He	25

TEMP C	WFS m/min	Amp I	Volts V	FRQ Hz	TRAVEL SPEED run/min	HEAT INPUT kj/min	DEPOSITION RATE Kg/ Hr
50	6.5	105	20.5	90	444	0.30	3.76
60	7.5	115	20.6	130	536	0.47	3.82
70	7.8	121	20.8	150	636	0.48	3.90
79	7.9	129	21.8	180	728	0.55	4.01
80	7.9	130	22.1	183	730	0.56	4.05

Table No. 4.2
Welding Parameters for Tandem Welding

WELDING PARAMETER							
DESCRIPTION SINGLE WIRE WELD		MATERIAL GEADE - X65 DIA - 18" WALL THICK - 22/24mm					
PASS	PROC-ESS	ELECTRODE				SHIELDING GAS	
		POLARITY	BRAND	BATCH	SIZE MIN	TYPE	FLOW L/MIN
ROOT	GMAW	DC +VE	LA 100	EDPN 9241	1.0	82.5%Ar/12.5%CO2 / 5%He	25
HOT PASS	GMAW	DC +VE	LA 100	EDPN 9241	1.0	82.5%Ar/12.5%CO2 / 5%He	25

FILL 1	GMAW	DC +VE	LA 100	EDPN 9241	1.0	82.5%Ar/12.5%CO 2 / 5%He	25
FILL 2	GMAW	DC +VE	LA 100	EDPN 9241	1.0	82.5%Ar/12.5%CO 2 / 5%He	25
FILL 3	GMAW	DC +VE	LA 100	EDPN 9241	1.0	82.5%Ar/12.5%CO 2 / 5%He	25

TEMP C	WFS m/min	Amp I	Volts V	FRQ Hz	TRAVEL SPEED run/min	HEAT INPUT kj/min	DEPOSITION RATE Kg/ Hr
50	6.5	115	20.8	100	444	0.32	2.02
55	6.7	122	21.5	120	444	0.34	2.03
62	6.9	124	21.6	135	444	0.34	2.04
64	7.0	125	21.7	140	444	0.34	2.05
70	7.5	130	21.7	190	444	0.34	2.06

(b) Analysis

(i) **Temperature Profiles** - The trial was to evaluate the maximum temperature generated on the PBJ with an aerogel blanket of 5.5 mm nominal thickness as compare to 2.5mm nominal thickness.

2.5 mm thickness of Aerogel Blanket for PBJ

	Min temp °C	Max temp °C
Single wire	50	80
Tandem wire	50	75

5.5 mm thickness of Aerogel Blanket for PBJ

	Min temp °C	Max temp °C
Single wire	50	90
Tandem wire	50	81

The results of the trials revealed that the estimated deposition rate for the tandem GMAW is about twice that of the single wire MIG .The arc on time for the tandem GMAW and single wire GMAW was 50 minutes. This showed that the productivity of the tandem is higher than that of the single wire MIG.

V CONCLUSIONS & FURTHER SCOPE

(a) Conclusions

(i) Under the conditions used for the trials, the results revealed that with the 2.5 mm nominal thickness aerogel blanket, the PBJ can with stand the welding conditions without being deformed, even though the PBJ was hotter.

(ii) A complete weld was obtained using for the PBJ with insulation blanket of 2.5mm thickness for

- Single wire GMAW maximum temperature of 80 °C.
- Tandem wire GMAW maximum temperature of 75 °C.

(iii) The feasibility of the tandem GMAW is about twice that of the single wire GMAW.

(b) Recommendation for Further Work

(i) 2.5 mm aerogel blanket can be used in place of 5.5 mm aerogel blanket.

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