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PERFORMANCE ANALYSIS OF SMAW WELDING AND GMAW-FCAW COMBINED WELDING FOR PIPELINE CONSTRUCTION JOBS AT SSGC.

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ABSTRACT: The pipe-line construction industry broadly uses welding processes in pipeline development to connect pipes before laying it down under the surface. SMAW welding process which is also known as 'Stick Welding' is the most dominant and common welding process. SMAW process poses a lot of limitations in terms of weld integrity, quality, productivity of overall job, and profitability owing to its manual nature. It thus affects the overall efficiency of pipe-line construction jobs. Such an operation is obvious candidate for automation. A Semi-Automatic system is recently procured at SSGCL (Sui Southern Gas Company Ltd) which employs combination of FCAW and GMAW welding processes. This study aims at deriving a performance analysis between the Combined FCAW-GMAW process and the existing SMAW process. This semi-automatic combined FCAW-GMAW process may prove to be the answer to limitations posed by SMAW Welding process in aspects of overall productivity, weld quality, and cost of pipeline construction jobs at SSGCL (Sui Southern Gas Company Ltd).

Keywords: SMAW, GMAW, FCAW, Pipeline Construction, Welding Processes, Mechanized Welding.

INTRODUCTION

Pipeline is used to transfer gases or fluids from one place to another place by connecting pieces of lengths of pipes together. The pipeline construction industry uses the welding processes extensively before laying it down under surface. For development of one kilo-meter pipeline, almost 40 to 80 welding operations are performed. Conventionally, the SMAW process, often known as Stick welding process, is the most dominant and most commonly used process in Oil & Gas industry pipelines. This process was developed over a hundred years ago and remains most widely used process to date.

Shielded Metal Arc Welding is an arc welding process which uses metal electrodes covered with shielding material as consumable. SMAW although has a lot of advantages which make it a good choice for a number of applications. However, it definitely incorporates some limitations in it that make other welding processes a better choice for certain application. For SMAW welding, highly-skilled welders / operators are required and as the process is manual and not automated, it usually has relatively lower deposition rates and thus lower productivity in comparison to automated processes. Welds developed with SMAW require extra clean-up, has greater metal wastage owing to the discarded electrode stubs and has relatively higher probability of occurrence of welding defects due to higher human involvement. The SMAW process is relatively lesser productive in comparison to continuous wire-fed processes and usually costs more given above limitations. A case study shows that more than 30, 00,000 welded joints were developed in the 3,500 KMs Alaska-Pipeline Project (Adu and Danquah, 2016) Such a repetitive operation of welded joints is an obvious candidate for mechanization. A mechanized process would furnish large gains in terms of profitability and productivity – although in right applications. The paramount advantages could be; i) Weld-Quality Improvement, ii) Increase in productivity and output, iii) Decrease in electrode wastage.

Flux-Cored Arc Welding is a semi-automatic welding process which uses continuously fed wire / electrode as consumable. The consumable wire / electrode in FCAW is flux-cored and provides its own shielding to the weld pool as it progresses. FCAW sometimes uses external-shielding as well depending on application of the process.

MATERIALS AND METHODS

Flux Cored Arc Welding of X- 80 grade pipes on U-groove weld type was performed for long-distanced pipe-line construction in case study of (Alkahla and Pervaiz, 2017). The paper although didn't refer to anything about other very important types of joints used in pipe-line construction like V type, T type, J type joints. The mentioned system uses a guide-band, a welding-carrier, a source of welding with automatic-control system, a wire-feeder and other accessories. Using this system, the mechanical tests of welded joints were performed. Obtained results indicate that the subject system can help in improving the welding process in aspects of inherent quality of weld joints and mechanical properties as well while reducing sharply the over-all cost of welding.

The use of GMAW process for development of root pass and use of FCAW for filling and capping passes while using the semi-automatic welding system on API 5L X-80 and X-70 grade pipes was carried out in (Antonini, 2014). ER70S-6 was used as consumable for GMAW process and for FCAW process E81T1-Ni1C was used. The process involved usage of a gas mixture of 80% Ar and 20% CO2 as external shielding gas. The obtained results provide information which supports the application of subject technology in application pipeline construction of X-80 and X-70. The information in this study furnish as base for our case study.

RESULTS AND DISCUSSION

In SMAW, Miller-BigBlue-500 Diesel Engine Driven Welder/AC Generator was utilized. For Combined process, in GMAW (root pass), Miller-PipeWorx-400 CV/CC inverter was employed, a PipeWorx-300-A MIG Gun with an automatic wire feeder was used. For Combined Process, in FCAW (Fill / Cap passes), Miller-XMT 450 CV/CC inverter was employed, with AWS Comet MK-V bugs for welding.

Pipe of API 5L X-70 Grade was used as base metal. In SMAW Process – E-6010 for Root pass, and E-9010 for fill / cap passes were used as consuamables. In Combined Process – ER-70S-6 for GMAW, and E-81-T1-NiMJ for FCAW was used. In SMAW, Miller-BigBlue-500 Diesel Engine Driven Welder/AC Generator was utilized.

The combined FCAW-GMAW process and SMAW process were performed con-currently on 24” Dia pipe. Welding was carried out in 5G-fixed position. Care was taken to deposit uniform beads of welds having no visible defects during visual inspection. Initial tries with combined FCAW-GMAW process yielded welds with cluster porosity (Fig. 1) due to open atmosphere welding. After proper care a sound weld (Fig. 2) was attained. After visual inspection, radiographic tests were carried out (Fig. 1, 2). Test coupons were cut and sent for destructive mechanical testing to M/s. Karachi Shipyard & Engineering Works Limited. Evaluation was done on bases of Weld Metal integrity, operating characteristics, and mechanical properties of welds. Aspects of productivity and weld-metal integrity which were subjective to operating parameters were accounted for as well. A ‘Procedure Qualification Record (PQR)’ was developed for each process using the optimum range of operating parameters.

After procedure qualification, WPS (Welding Procedure Specifications) was recorded for both the processes employing the optimum parameters from respective PQRs.

For the edge on productivity of processes over one another to be determined, actual time consumed per joint for both the processes was compared. Calculated time for FCAW-GMAW welding joint was also compared to the actual time which turns out to be similar. The time-consumed comparison was performed for 24” Dia pipe. Repair percentage for both the processes was also compared.

Observations on Radiograhic Test Reports: In welds development for both processes, initial tries gave out welded joints with common defects like porosity. A few tries and proper care yielded perfect welded joints. Radiographic reports of both welds for combined FCAW-GMAW process are attached as Fig. 1 & 2. In combined FCAW-GMAW process particularly, cluster porosity turned out to be major defect in initial trials. Cause of cluster porosity was mainly interrupted shielding-gas path. Proper care was given to shielding-gas circuit after which defect-free and sound welded joints were achieved.

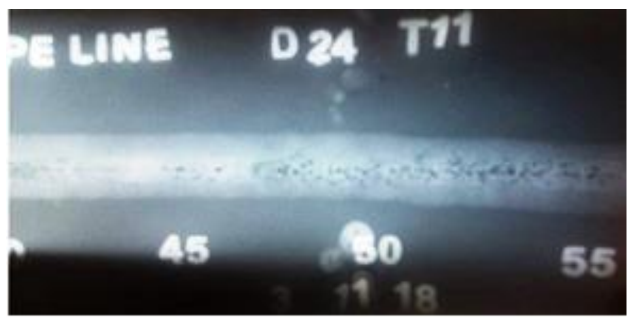

Figure 1 Radiographic Test report of of initial FCAW-GMAW process welds with cluster porosity.

Figure 2 RT report of defect-free Welded joint FCAW-GMAW Process

Observations on Destructive Testing: Weld joints of both processes were sent for Destructive- testing to M/s. Karachi Shipyard and Engineering Works Ltd. Obtained results were compared in Fig 3. Results were then recorded in PQRs. Fig 3 & 4 indicates the difference in

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strengths of welded joints of both processes (Huilin et al., 2014; Menon, 2011; Williams et al., 2001).

Observations on Operating Characteristics: Operating parameters recorded in respective WPSs Welding Procedure Specification were used to develop welds of both the processes. Comparisons of important factors which directly affect the productivity are tabled in Table 1.

As indicated in Table 1 below, elapsed time per weld for combined FCAW-GMAW process is relatively lesser than time elapsed for SMAW joints. Although, the travelling speed for SMAW weld passes is higher than travelling speed for FCAW-GMAW weld passes, however, rates of metal deposition of SMAW process is far lesser than that of FCAW process. The deposition rate of FCAW is 3.2 Kg/hr in comparison to to 0.8 Kg/hr for SMAW process (Batista *et al.*, 2016; Boekholt, 2000). Also, a SMAW weld takes 7 passes in comparison to 4 passes for FCAW-GMAW weld.

Costing: Looking from the economic point of view, costing is important factor for comparative analysis Cost of consumables for both the processes are compared below in Table below;

Use of WeldCalc Software: The elapsed time per weld in actual for FCAW-GMAW combined process is compared to the calculated time with help of WeldCalc software by AWS Ltd (Yapp and Blackman, 2004). With weld time efficiency at 70%, the results obtained are largely similar to actual time elapsed. Screenshot from WeldCalc software indicating time elapsed per joint and electrode consumption is attached in Fig 6.

Consumables for 24" Dia, 0.469" Wall Thickness				
Process	**Electrode**	**Weight Kg/Joint**	**Cost per Kg - PKR**	**Cost – Consumed PKR**
SMAW	E6010 – 1/8"	0.54	300	162
	E6010 – 5/32"	0.34	300	102
	E9010 – 5/32"	0.34	405	137
	E9010 – 3/16"	3.54	405	1433
	Cost of Consumable per joint			**=1834**
GMAW-FCAW	ER 70S-6 – 1.2mm	0.7	260	182
	E 81 T1-NiMJ – 1.2mm	1.8	335	603
	Cost of Consumable per joint			**=785**

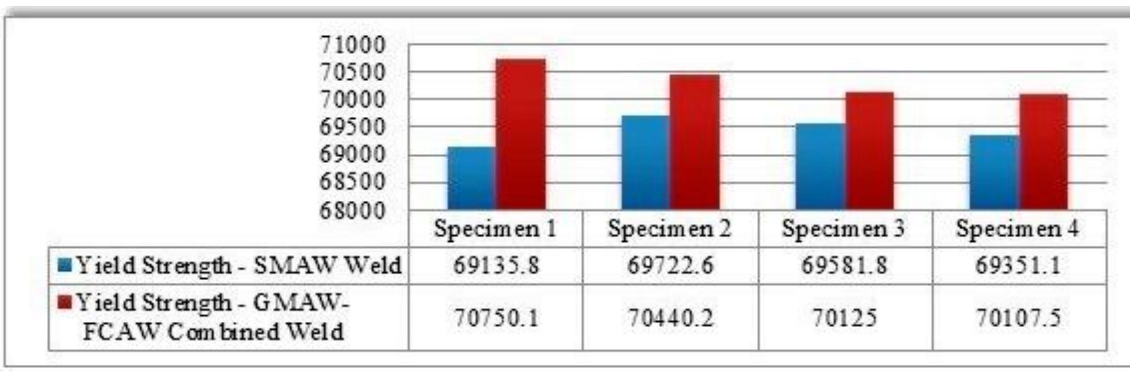

Figure 3 Comparing the Yield-Strengths of specimen cut from both processes

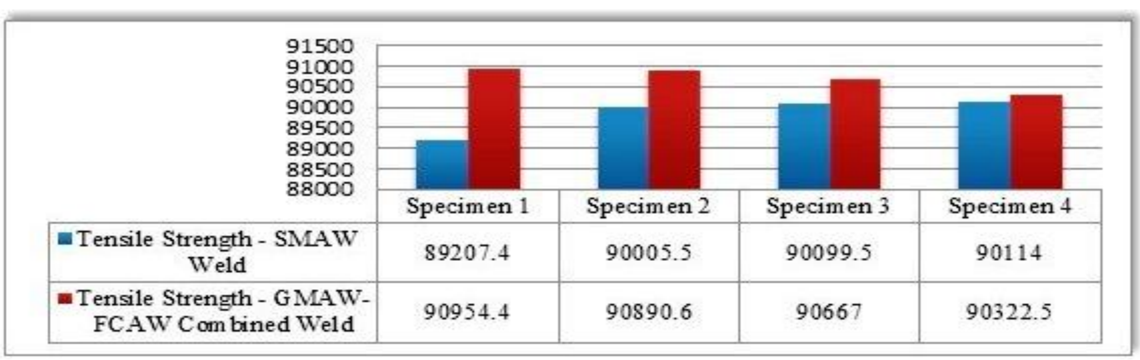

Figure 4 Comparing tensile strengths of Specimen cut from both processes

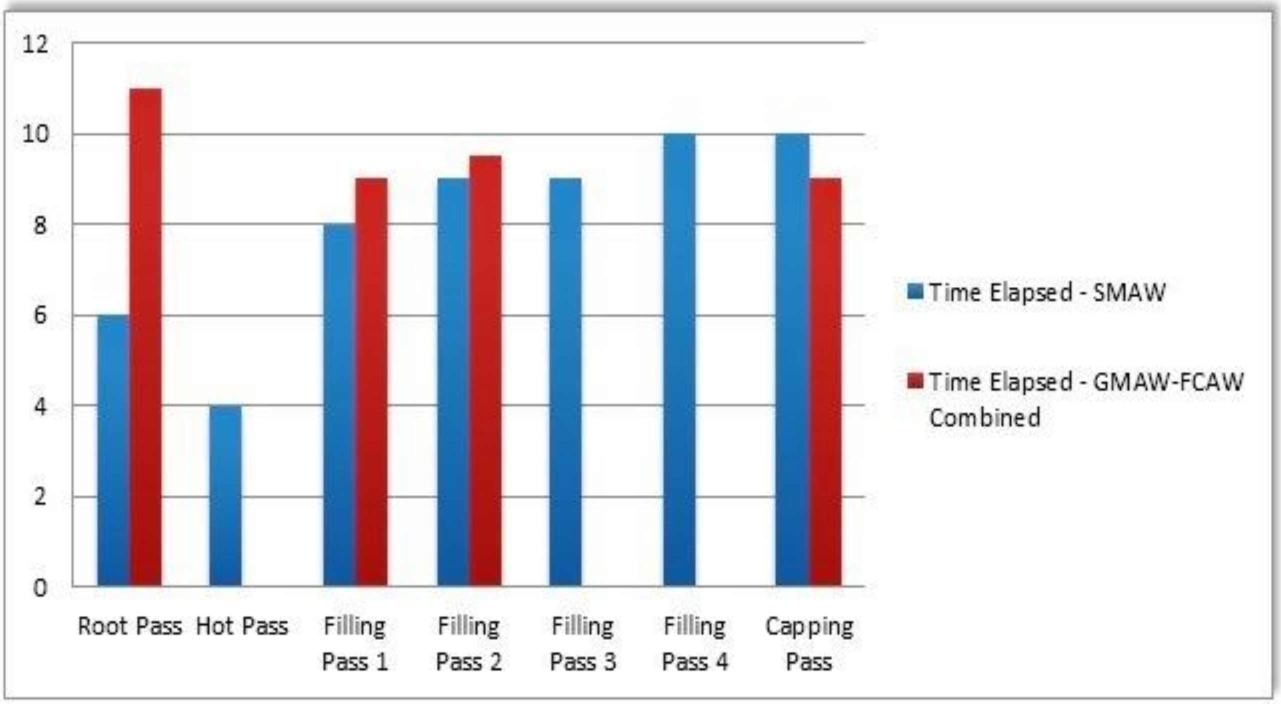

Figure 5 Comparing the Elapsed time per pass

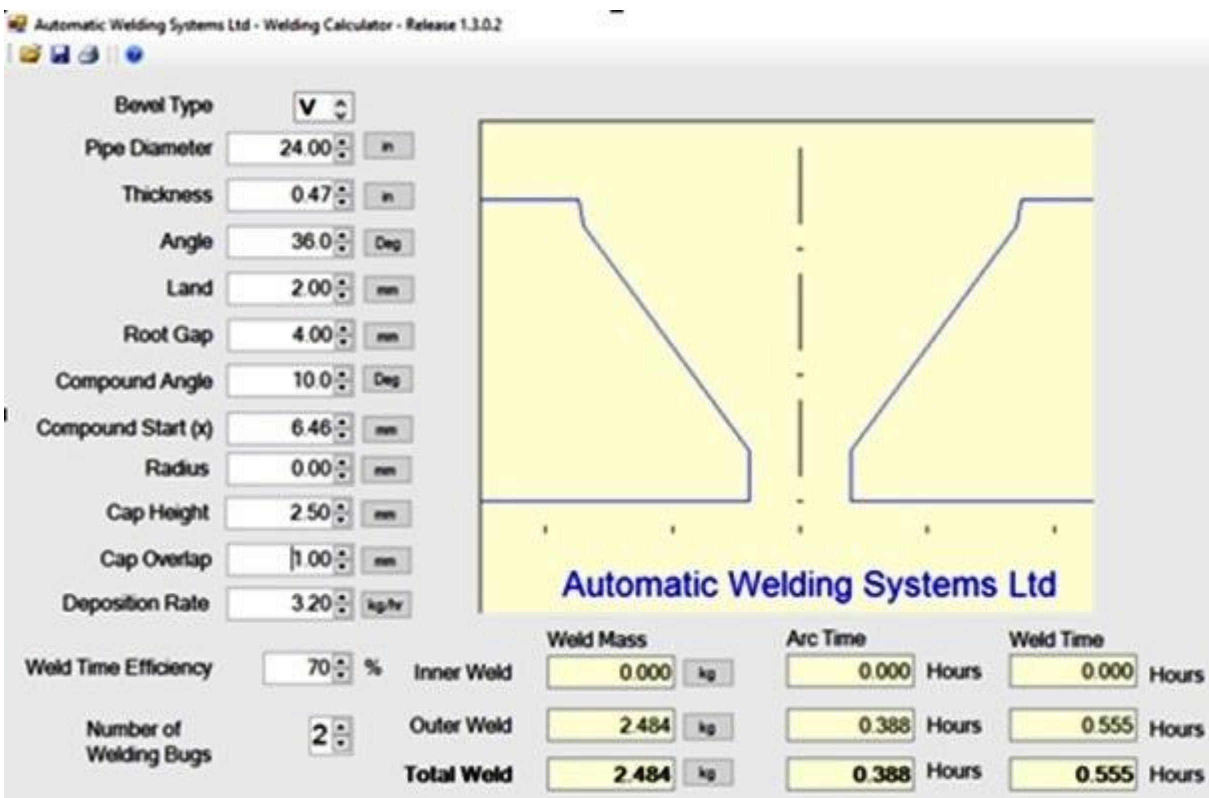

Figure 6: Screenshot of the WeldCalc software

Table 1 - Operating Characteristics

Sr. No.	Parameter		SMAW	GMAW-FCAW
1	Pipe Size		24" Dia	24" Dia
2	No. of Passes		7 Passes	4 Passes
3	Electrode / Wire Speed.			**(inch/min)**
	a.	Root Pass	N/A	98.4 – 118
	b.	Filling Pass 1		280
	c.	Filling Pass 2		310
	d.	Capping Pass		270
4	Travel Speed.		**(inch/min)**	**(inch/min)**
	a.	Root Pass	13-15	8-10
	b.	Hot Pass	16-18	--
	c.	Filling Pass 1	8-10	6-7
	d.	Filling Pass 2	10-11	5.5 – 6.5
	e.	Filling Pass 3	7-8	--
	f.	Filling Pass 4	9-10	--
	g.	Capping Pass	6-7	6-7
5	Time per Pass (average)		**(min)**	**(min)**
	a.	Root Pass	5-6	9-11
	b.	Hot Pass	3-4	--
	c.	Filling Pass 1	6-8	7-9
	d.	Filling Pass 2	8-9	7.5-9.5
	e.	Filling Pass 3	7-9	--
	f.	Filling Pass 4	8-10	--
	g.	Capping Pass	8-10	7-9
6	Time Elapsed per joint		49 - 60	33 – 40 min

Conclusion: This experimental study indicates that the combined GMAW-FCAW process is better suitable for the application under study. Although there were complications in the beginning, specially relating to occurrence of porosity due to wind, but proper care resulted in development of sound weld joints with good mechanical properties and weld integrity. Combined GMAW-FCAW process is answer to many limitations posed by manual SMAW process in terms of production, cost optimization and better mechanical properties. Quality of weld for Combined GMAW-FCAW system is better than SMAW welds in terms of weld bead quality, integrity, and lesser number of repairs. Cost of resources will be minimized in Combined Welding System in context to manpower, wastage, power loss, time loss, etc. It may lead to better market condition and economy however small but effective. Further it can be developed for future working on bigger pipe and pressure vessel welding for circumferential joints.

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