ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 9, March 2013

Integrity Assessment of Weldment Zone of Selected Oil and Gas Pipelines

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***Abstract*— this work examines the integrity of weldment zone of an oil and gas pipeline used to convey petroleum products. To accomplish this in an efficient way, experiments on a variety of welding parameters were conducted on American Society of Testing Materials (ASTM) A109SCH40 steel specimen, welded by metal arc welding. Thus, the influence of welding current, arc voltage, welding speed, pipe thickness and depths of penetration on some mechanical properties of the pipeline steel were studied. The findings from this work shown that an increase in the welding speed at a constant arc voltage and current will lead to increase in penetration until maximum penetration is achieved. The practical implications of this research show that optimal weld penetration can be achieved under certain circumstances. Further researches are needed to explain how the weldment mechanism changes with varying welding conditions.**

***Index Terms*— Depth of Penetration, Guided Bend, Welding Current, Weldment Zone.**

I. INTRODUCTION

Pipelines are used to transport fluids such as petroleum products, gas, ethanol, biobutanol and highly toxic ammonia and this necessitates the need to ensure the safety of pipelines hence the focus of this research. In structural fabrication welding occupies a vital position and it entails joining of material usually metals or thermoplastics which is achieved by causing coalescence; melting the work pieces, adding filler material to form a pool of molten material (i.e. the weld pool) which solidifies later to become a strong joint with pressure sometimes used in conjunction with heat or by itself to produce the desired weldment [1]. It was also reported that the energy required for welding operations could be tapped from different sources: gas flame, an electric arc, a laser, an electron beam, friction and ultrasound [2]. As an industrial process, welding could be performed in different environment including open air, under water and outer space [3],[4]. As such, welding is a potentially hazardous undertaking which attract precautious measures to forestall burns, electric shock, and vision damage, inhalation of poisonous gases and fumes, and exposure to intense ultraviolet radiation. Presently, the science of welding is in its advancement stage. Robot welding is thus a commonplace in industrial technology and researchers had gained some level of breakthrough as they develop new welding methods and achieved greater understanding of welding quality and properties [5],[6]. However, the integrity of welded parts of pipelines should be examined regularly to assess and fish-out potential risks and flaws so as to prioritize available mitigation techniques in ensuring safety of lives and properties in the community. The integrity assessment of pipeline goes beyond maintaining it to a minimum requirement code; rather an aging asset requires increasing care and not constant care as the case maybe [7], [8]. Amongst the major causes of pipeline failures are corrosion, gouges, dents and etc. hence prevention, detection or mitigation of defects are the keys to pipeline integrity. The two main approaches employed in the assessment of weldment in pipeline are the Non Destructive Test (NDT) and the Indirect Indicators There are four necessary components to make a weld, it includes: the metals itself, heat source, filler materials and some kind of shield from the air. In terms of quality, the amount of spatter and probably the microstructure of the heat affected zone are the parameters used to check for a good weld [9]. Against this background, the control process/system observed in arc-welding seems to be the best. It is imperative to evaluate the effects of welding parameters vis-à-vis: welding current, welding voltage and welding speed, on the weldability of the materials during the arc-welding process, hence the thrust of this work.

II. EXPERIMENTAL METHODOLOGY

The steel pipes used in this work have the dimension of four feet 1,176 mm long, 6 mm thick (158 mm, and 164 mm inner and outer diameters), 4 mm (158 mm, and 160 mm inner and outer diameters) respectively. The specimen was sectioned into eighteen (18) samples with each having an arc length of 60mm and this dimension was obtained using a slitting machine which runs a cutting speed of 6,650 rpm (80m/sec) with cutting disc of nine (9) inches (220.5 mm) wide. The sectioned samples were then smoothened at the edges with the aid of flat file in order to remove steel fillings or slags. The edges of the sectioned steel pipe were prepared to a single V-butt joint having a bevel angle of 60^o after which the sectioned steel pipes were welded. Furthermore, maximum alignment tolerance of one (1) was used for twenty percent (20%) of the pipe thickness. To ensure initial proper alignment, clamp was used to hold the work piece, a piece of angle iron help to make a good jig for a small diameter pipe, while a section of channel is more suitable for larger pipe diameter. Tag weld was used to hold the specimen in place temporarily, four tacks was made considering diameter of the samples which held the pipes directly opposite to each other. The tack weld was not more than twice the pipe thickness and it was ensured to have a good fusion and same quality before it was thoroughly cleansed for final welding. Moreover, the finished weld was

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ISO 9001:2008 Certified
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inspected for undercut, overlap, surface checks, cracks, and other defects. Also, the degree of penetration and extent of reinforcement of the welds were examined as they are important factors which reflect the quality of a weldment. Test samples were produced at constant current and varied weld speed and constant weld speed and varied current supply, and thereafter, test samples for inspection, acid etch, guided bend, tensile strength and hardness tests were obtained so as to evaluate the mechanical properties of the weldment. To determine the soundness of the weld, Acid Etch test was performed on the cross-section of the joint using a solution of hydrochloric acid as the working fluid. The acid reacts with the edges of the cracks in the welded metal and reveal weld defects if present. Also the Guided Bend Test was carried out to measure the quality of the weldment at the surface and root of the welded joint, together with the degree of penetration and fusion at the base metal. To meet the requirements for the Guided bend test, the specimens were bent at one hundred and eighty degrees (180^{o}) and to be passable, no cracks greater than 3.2 mm in any dimension should appear on the surface. The strength along with the hardness of the weld joints was measured through the Tensile and Hardness Tests respectively. In deductions, consideration was given to welding parameters such as welding current, voltage and arc traveled speed. These parameters were varied over a large range. Each value was recorded for every different type of weld to permit reproducibility, and to achieve an explicit analysis of each parameter, they were varied one after the other. The 6mm and 4mm nominal diameter were analyzed separately and compared so as to deduce the effect of geometrical size of the components on the residual stresses.

III. RESULTS AND DISCUSSION

Table 1 and 2 contain the spectrometric analysis of the pipeline samples and the chemical composition of the steel electrode used in this study respectively.

Table 1 Chemical Composition of Steel Sample Used (Carbon Steel: ASTM A109 SCH40)

Element	C	Si	Mn	P	S	Cr	Ni
% Composition	0.15	0.26	0.88	0.008	0.025	0.14	0.16
Element	Mo	Cu	Al	Sn	V	Ti	
% Composition	0.03	0.22	0.017	0.028	0.002	0.001	

Table 2 Chemical Composition of Electrode Used (Gauge: 10 Low Hydrogen Electrodes)

Element	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O
% Composition	25.16	8.15	0.54	0.36	0.20	0.72	0.50
Element	CuO	ZnO	PbO	H_2O	TiO_2	LO	
% Composition	0.32	0.009	0.001	0.32	0.001	0.01	

From the graph of weld penetration against the welding speed at constant current (Figure 1), the 6 mm and 4 mm behaved in a nearly opposite manner from onset of the experiment up to 6.6 mm/sec welding speed. Weld penetration observed in 6mm sample started by increasing in value, forming a convex like arc-line whereas the 4 mm pipe begin by decreasing in value of the weld penetration up to 6.1 mm/sec before it started increasing in value, creating a concave like arc-line and both opposite lines meet at the welding speed of 6.1 mm/sec which suggests the optimal welding speed for both 6 mm and 4 mm steel samples under investigation. The inclination change immediately as the 6 mm sample forms concave arc up to the welding speed of 6.6 mm/sec while the 4 mm sample in turn forms convex shape at that same point. Conversely, both samples (6 mm and 4 mm) behavior changed as the depth of penetration obvious in both samples decrease drastically, worse still is the 6 mm sample in which the depth of penetration falls recording the least as the speed of welding increases before recuperating roughly at 7.1 mm/sec when it started increasing in values weld penetration. In a nutshell, the best welding speed for the 6 mm sample is approximately 6.65 mm/sec whereas its worse welding speed is infer to be 7.1 mm/sec. On the contrast, the 4 mm sample has 6.5 mm/sec to be its best welding speed yet it has the same value as the worse welding speed just like its counterpart. Apart from the optimal welding speed, the 4 mm sample recorded higher values of weld penetration across the various welding speeds under discussion. In view of weld penetration vis-à-vis welding current at constant welding speed (Figure 2), both samples (6 mm and 4 mm) studied under constant welding speed and varied welding current showed almost similar characteristics. The curve lines followed the same pattern and the noticeable disparity is seen along the respective depth of penetration of the weld, so far the 4 mm sample maintained higher value of weld penetration at roughly 4 mm difference across the varied welding current examined. Despite the constant penetration of the weld palpable at the welding current range between 140 amp to 160 amp in 6 mm sample, it is evident that the weld penetration increases with increase in welding current throughout the rest of the experimental current supplied. In a like manner, the 4 mm sample kept increasing even as the welding current increases provided the welding speed remains constant. From the ongoing, it could be deduced that the depth of penetration increases proportionately. The theoretical disparity or correlation existing between the mechanical properties (hardness and tensile strength) of steel is (±10), and the hardness and tensile test looked into at different welding current demonstrated this phenomenon in both samples studied (Figures 3, 4, 5 & 6). Also, both hardness and tensile strength curve formed sinusoidal or wavy lines. Taking into account 6 mm sample, the hardness curve (Figure 3) and the tensile strength (Figure 4) followed the same pattern of line, yet the tensile strength at the lowest welding current is higher than the conforming hardness features at that same welding current. In addition, both properties attained their peak at the same welding current range of 100 amp to 120 amp, nevertheless the peak point of hardness is more than that of tensile strength. In conjunction, hardness and tensile strengths of the 6 mm sample recorded its lowest values at the same welding current. Likewise the 4mm sample has its mechanical properties (hardness and tensile strength) hit the highest value at the lowest welding current and the lowest value at the highest welding current. The hardness and tensile

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 9, Marc

strength assessed in 4 mm sample yielded almost the same kind of graph, and among the peculiar characteristics noticed is that the increase in welding current leads to decrease in both hardness and tensile strength of the steel and vise versa. This is noticeable throughout the welding current considered. In a bid to ascertain the quality and integrity of weldment, the plot of guided bend test against different tensile strength values of both 6mm and 4mm samples (Figure 8), have shown that the guided bend test conducted in 4mm sample is inversely proportional to the tensile strength of that steel up to the 64 MPa value after which the bend began to increase in value gradually. The maximum bend evident in 4 mm sample occurred at the least tensile strength of this steel. Between the ranges of 63 MPa to 64 MPa of strength there are almost constant and also the least values of bend in existence. The bend in 4mm sample is elastic as it started from the least value and cut across all the values of the tensile strength under investigation. On the contrary, the 6mm sample exhibit a strong sinusoidal curve and recorded its maximum value of 4.2 mm amidst the values of tensile strength considered, though unlike the 4mm sample, the bend in 6mm sample initiated at the tensile strength value of 59 Mpa and terminated at 63 MPa. The apparent theoretical disparity (±10) between hardness and tensile properties of steel still holds in both 6 mm and 4 mm steel samples as it is the difference existing between the guided bend values studied against the corresponding hardness values obtained from the experiment (Figure 9), and the guided bend values examined against the tensile strength discussed earlier. Moreover, the bend in question began to generate from 55 MPa through 61 MPa of the mechanical tensile strength. The guided bend investigated so far behaved like its counterpart as it decreases in value as hardness increases in value throughout the experiment. The 6 mm sample created its first bend at the same 3.8 mm value of 4 mm sample. It has a similar trend line as that of tensile strength and achieved its maximum value approximately at the same point.

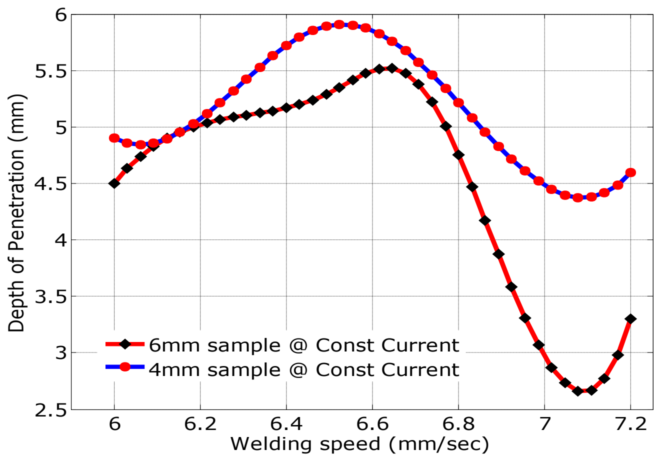

Fig. 1: Weld Penetration at Constant Current against

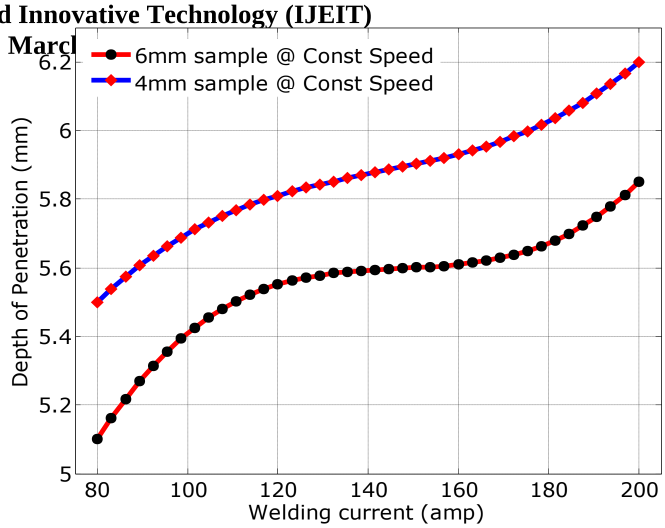

Fig. 2: Weld penetration at constant speed against welding current

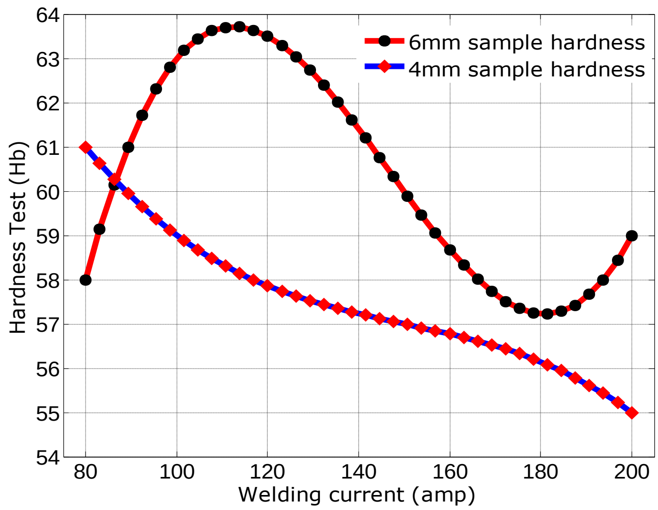

Fig. 3: Hardness variations in both samples against varied welding current

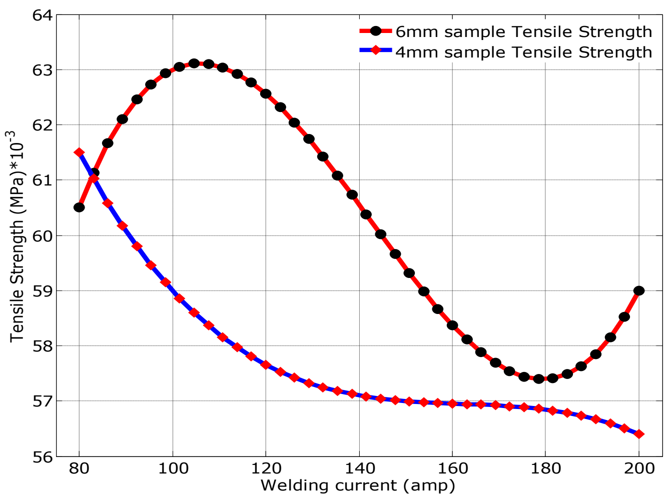

Fig. 4: Tensile strength variations in both samples against welding current

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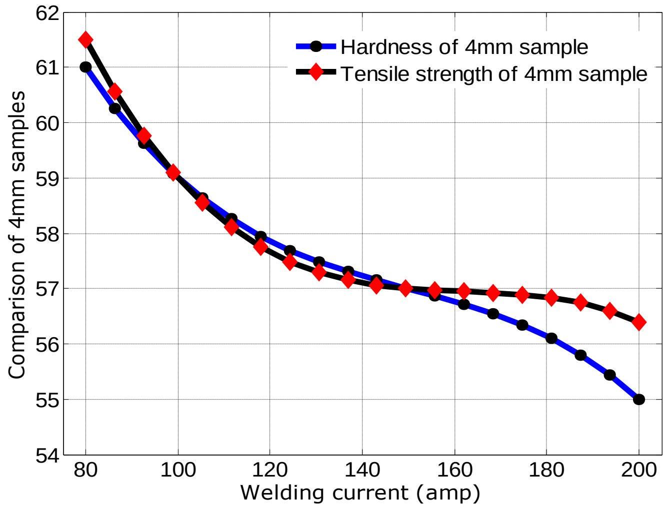

Fig. 5: Comparison of mechanical properties of 4mm sample against diverse welding current

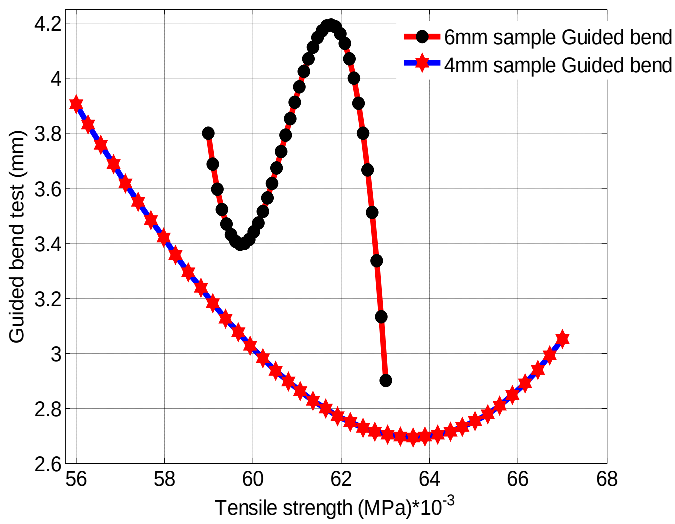

Fig. 8 Guided bend variations in both samples against tensile strength

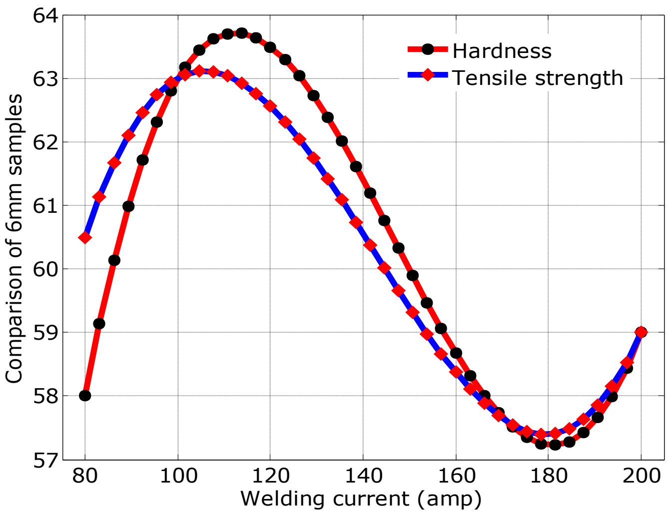

Fig. 6: Comparison of mechanical properties of 4mm sample against diverse welding current

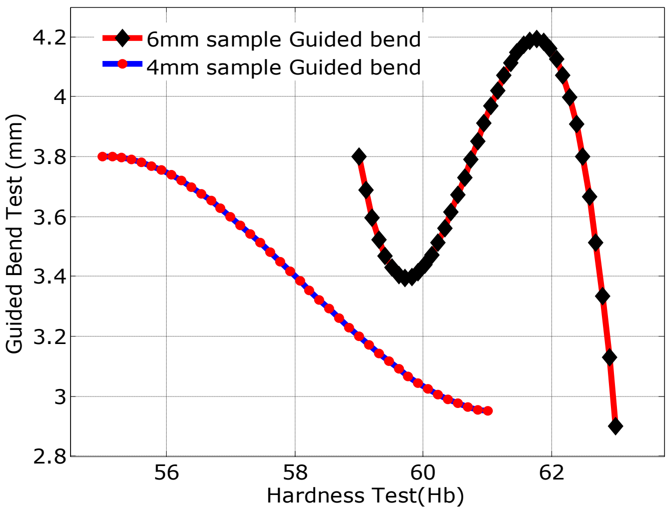

Fig. 9 Guided bend variations in both samples against hardness

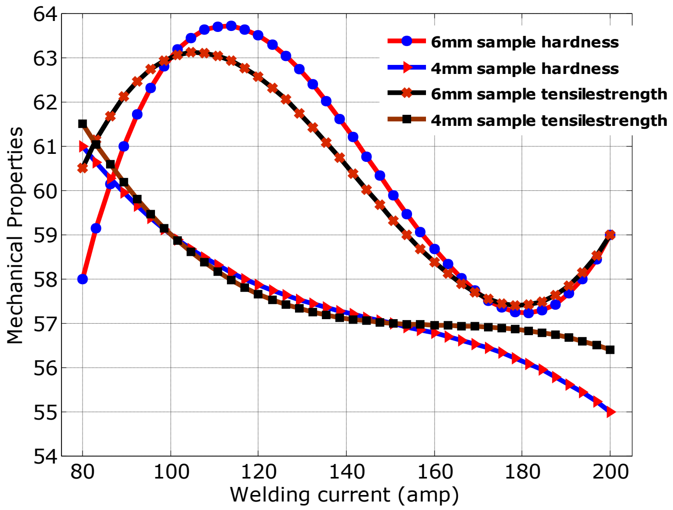

Fig. 7: Mechanical properties against welding current at constant speed

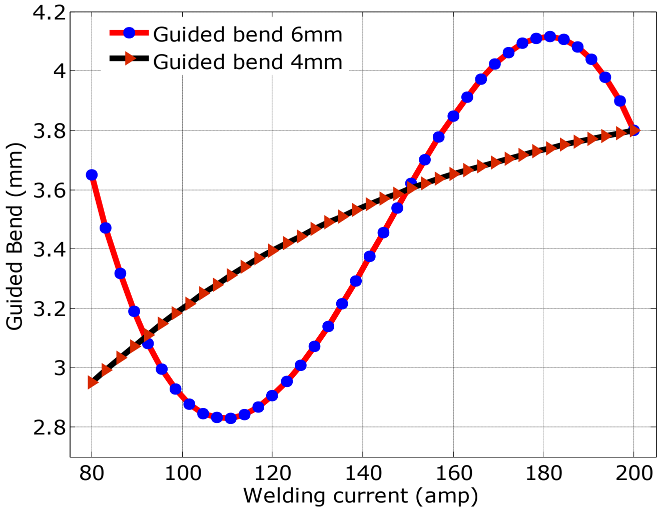

Fig. 10 Guided bend variations in both samples against welding current

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 9, March 2013

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