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Design of Experiment of High Pressure Steel Tank Using Tandem Submerged Arc Welding

Prin Boonkanit[1,a*], Wittaya Pansong[2,b]

[1,2] Department of Sustainable Industrial Management Engineering, Faculty of Engineering, Rajamangala University of Technology Phra Nakhon, Bangkok 10800, Thailand

[a]prin.b@rmutp.ac.th, [b]apansong@gmail.com

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Abstract. The objective of this research is to investigate the appropriated Tandem Submerged Arc Welding (TSAW) by Punch through technique for high pressure steel tank in ship building industry. Electrode Type AWS A5.17 EM12K and powder flux type AWS A5.17 F7A6 have been applied with electric current at AC+ 550-700 Amp/DC 460-610 Amp. The welding travel speed is controlled between 515-590 mm/min with arc length between 25-30 mm which SM400 steel type is 25 mm thickness. The welding is in horizontal position without any bevel on the steel piece. Studying the suitable parameters from the experiment type 2^4 of this procedure experiment, the result has been found that the most suitable parameter set up for this welding is DC460, AC550, ST515, AL25. The experiment follows AWS D1.1 standard with 100% full penetration, tensile value at 542.61 N/mm^2. Welding line supports impact test at 0°C with average value of 66 Joules, average hardness value at 156.4 HV, bending at 180°. With out any defected found. Moreover, this method can be reduced welding cost around18,482 baht/day and also increased the welding lenght around 168%.

Introduction

At present, demand of advanced joining methods with high productivity is increasing in ship building and other fabrication industries. Submerged arc welding (SAW) is traditionally considered as an efficient and highly productive joining technology for medium to high thickness steels. Improvements for welding technique are desirable as it is one of the methods showing greatest potential for application in industry [1]. The commercially available welding should be considered in terms of their suitability for ensuring arc and metal transfer stability, performance, and weld quality. Especially, for the high risk industry such as petrochemical and navy logistics etc. such as research papers from Moeinifar et al. [2,3]. Which welding quality is very important parameter for the safty, duraablity and also economics. The development of industries regarding huge steel structure needs expertise on development of efficient arc welding procedure. SAW is one of the most effective method for metal welding. However, many companies have been struggling with the questions what is the suitable technique and parameters level to develop TSAW at the production stage and how to measure the TSAW particularly focused in the quality, cost and development time [4]. Due to the most obstacles that industrial face in analyzing the best alternative solution within the limited product is the knowledge available at this stage especially for high pressure steel tank ship building in Thailand.

Hence, the objective of this research is to design and develop the appropriate Tandem Submerged Arc Welding (TSAW) parameters by Punch through technique for high pressure steel tank in ship building industry. The challenge for the authors was to consider the core needs of parameters design whilst minimizing cost and ensuring the integration of quality aspects within the time constraints of customer requirement. Research methodology, design of experiment method, research result, and a case study in Thailand industrial are as follow;

Research Methodology

1. Experimental preparation

The experiment has been prepared the specimens by using standard SM 400 carbon steel, 180x600 wide, and 25 mm thickness. The arc welding of the two pieces is done without any space and corner bevel. The welding wire used is AWS A5.17 EM12K at 2.4 diameter.The powder flux is AWS A5.17, electric current of DC+ 460-610 Amp at major wire, and AC 550-700 Amp at trail wire. The welding wire is at the angle of 90°with the experimental pieces giving a space of 20 mm and 25-30 mm Electrod stick out. The welding speed is controlled between 515-590 mm/minute.

The experiment includes inspecting the completeness of welding lines following the inspection regulation according to AWS D1.1: 2010[5], inspecting the welding lines by using radiography following standard of AWS D1.1 Section 6 Part E, conducting tensile test by ASTM E8/E8M-11a[6], bending the sides of the work pieces at 180^{o} following standard of ASTM A370-13, ASTM E190-92 (2008). The impact test is in compliance with ASTM-E23 standard [7]. And the hardness test on welding lines as per ASTM E384-11e1 standard [8] by the research procedure is as demonstrated in Fig. 1 and equipment preparation is illustrated in Fig. 2.

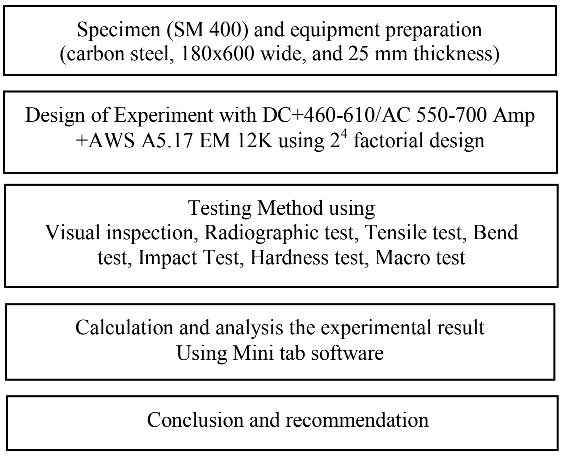

Fig.1. Experiment Procedure

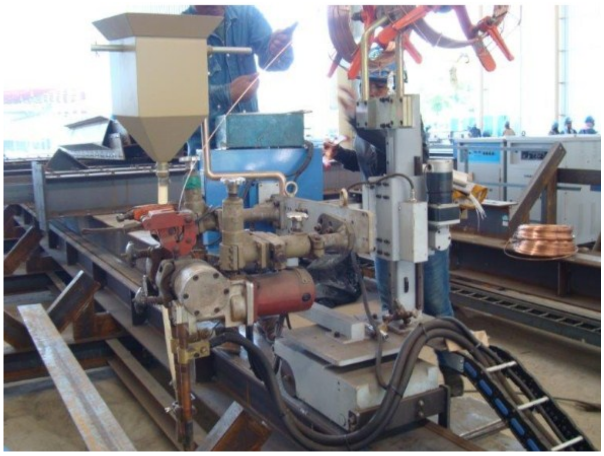

Fig. 2. Specimen (SM400) andequipment preparation

2. Design of Experiment

The study of parameters that have an effect on welding quality is done by adjusting parameters of Design of Experiment with DC+550-570/AC 460-480 Amp +AWS A5.17 EM 12K using 24 factorial. The required design matrix (Table 1) with a total of 16 experimental runs had been developed for the four welding factors. The upper (+1) and lower (-1) levels of all the four variables as shown in Table 2 had been established by trial runs prior to the actual welding to ensure deposition of an acceptable weld bead. The intermediate levels of -1, +1 of all the variables had been calculated as shown in Table 1.

Table 1. Parameter table and levels used in DOE study

Factor	Low (-1)	High (1)	Unit
Current (AC)	550	700	Amperage
Current (DC+)	460	610	Amperage
Travel speed (TS)	515	590	mm/min.
Arc Length (AL)	25	30	mm.

Two wires tandem submerged arc welding (TSAW) involve application of two electrode wires to form a single weld pool with one wire leading the other along the weld interface. Based on the tandem submerged arc welding process, this study reports on an experimental and optimization investigation of the weld geometry characteristics such as bead width, reinforcement form factor and penetration shape factor. The selected process parameters were welding amperage and welding voltage, and these were initially investigated to determine their effect on weld geometry. The experiment and collect data can be defined as per Table 2. The data collection uses L16 experimental design. The result of experiment with Hardness Vickers test (HV) is as shown below;

Table 2. Collecting data usingScreening DOE L16

StdOrder	RunOrder	CenterPt	Blocks	DC	AC	TS	AL	HV
12	1	1	1	610	700	515	30	147.73
8	2	1	1	610	700	590	25	149.20
5	3	1	1	460	550	590	25	149.90
13	4	1	1	460	550	590	30	154.77
16	5	1	1	610	700	590	30	155.60
3	6	1	1	460	700	515	25	165.10
4	7	1	1	610	700	515	25	166.17
2	8	1	1	610	550	515	25	164.83
14	9	1	1	610	550	590	30	164.63
10	10	1	1	610	550	515	30	167.87
7	11	1	1	460	700	590	25	158.67
1	12	1	1	460	550	515	25	156.40
6	13	1	1	610	550	590	25	149.67
11	14	1	1	460	700	515	30	148.57
15	15	1	1	460	700	590	30	152.77
9	16	1	1	460	550	515	30	154.70

3. Experiment on mechanical properties

A model relating the depth of penetration to the levels of one or more welding factors is an indispensable aid in the interpretation of results from an experimental design. In term of testing specimen, macroetching is applied, this method is used in the steel industry because it is a simple test that will provide information about the relative homogeneity of the sample. Testing Method are visual inspection, radiographic test, tensile test, bend test, impact test, hardness test, macro test. The Macroetching test process which has been implemented in this experiment. Calculation and analysis the experimental result using Mini tab software. The result of experiment on mechanical properties of the welding line is shown in the Table 3.

Table 3. The result ofexperiment on mechanical properties of the welding line

Tensile Hardness (N/mm^2)	Receive impact at temperature of 0°C (Jul)	Average hardness value (HV)
542.61	66	156.4

4. Result of Experiment

The result of development of Tandem Submerge Arc Welding (TSAW) and cost comparison between SAW and TSAW welding procedure by Punch through technique is illustrated in Table 4 below;

Table 4. Cost comparison between SAW and TSAW welding procedure

Welding Process	Time Preparation (min)	Welding time (min)	Weld length(m)	Total Cost (Bath/day)	Production Efficiency %	Welding Efficiency %
SAW	150	10	25	18,482	25	100
TSAW	20	1	67	18,482	67	168

Conclusion

This study was to evaluate welding strength of the SM 400 steel plate using Tandem Submerged Arc Welding by Punch through technique (TSAW) without bevel on the work piece. The result has been shown that the completed welding line with 100% penetration, international standard mechanical properties, and micros structure in compliance with steel structure's welding standard. The parameter which gives the highest effect on average hardness value is electric current AC. It can be increased hardness value by decreasing values of DC, TS and AL. The analysis result depicted this method can be increased mean of hardness value (HV) by decreasing current (DC) to 460 Amp., Travel speed (TS) 515 mm/min., and Arc Length (AL) 25 mm. The tensile hardness is 542.61 N/mm^2, Receives impact at temperature of 0°C is 66 Jul, and average hardness value of the welding is 156.4 HV. However, co-parameters between AC and DC, and DC and DL also have the highest effect on the hardness of the welding line in this procedure. In addition to the adequacy test performed, the validity of the results of mathematical modeling for prediction of depth of penetration was also tested. Based on this investigation it can be concluded that the developed model can be used to setup adequately the weld bead penetration within the specified limits of the process parameters. The experimental method can also be used to find optimum welding conditions for maximum weld bead penetration.

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