International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 6 Issue 11|| November 2017 || PP 17-23

Deformation of T-Connected Pipes DuetoWelding Process

Pham Son Minh[1],Ho Ngoc Son[1]
[1]HCMC University of Technology and Education, Ho Chi Minh City, Vietnam
Corresponding Author: Pham Son Minh[1]

Abstract: *Simulation tools are among the most powerful and cost-efficient ways to reduce welding deformation. In this research, a simulation tool combined with experimentsisused to evaluate the deformation of a structure comprising two perpendicular pipes. In the simulation, the linear elastic-shrinkage method using relatively new finite-element modeling softwaredeveloped by ANSYS Inc. is used to simulate the welding process and to predict the welding distortion of pipeswithdifferent thicknesses. For verification purposes, a series of experiments arealso performed using a fully automated welding system with a gas metal arc welding power source. The results show that using the same welding parameters, a thinner pipe will experience larger deformation. The maximum deformations are 3.53 mm, 2.32 mm, 1.78 mm, and 1.30 mmforpipe thicknesses of 2.5 mm, 3.2 mm, 4.0 mm, and 5.2 mm, respectively. When the pipe thickness is increased from 2.5 to 5.2 mm, the maximum residual stress decreases from 677 to 498 MPa.*

Keywords: *Welding simulation, pipe structure, pipe deformation, T-connection.*

Date of Submission: 10-11-2017 Date of acceptance: 21-11-2017

I. Introduction

A disadvantage of welding is the deformation of parts, which has become an important focus of research for the metal industry, especially with the trend toward thinner and smaller products [1,2]. In recent years, the development of high-strength steel has also created a trend for using thinner pipes in many industries [3]. However, as the materialsallowthe productstobecome thinner, the problem weld deformation (WD) arises in the assembly process, which comprises 48–50% of all thejoiningprocesses with the metal material [4]. The welding method is considered to be a critical aspect of pipe assembly, with weld metal accounting for at least 3–4% of the total steel weight of a machine [5]. Therefore, the product quality depends largely on the welding quality [6]. According to the American Welding Society (AWS), the cost of correcting WDcan be as high as 30% of the total fabrication cost [7]. WDcauses variations in the welding structure and decreases the dimensional accuracy and carrying capacity of pipe structures. Furthermore, it causes additional bending moments and stress concentration under working loads, these being the main reasons for the early failure of metal structures. Thus, studying how to reduce WD is very important for metal industries.

In the present study of WDinpipes, we used simulations and experiments to evaluate the deformation of a structure comprising two perpendicular pipes that are weldedtogether in a T shape. The simulationswereperformedin the ANSYS finite-element modeling (FEM) software using its heat transfer and structural capabilities. To verify the simulation results, we conducted a series of experiments on pipes with four different thicknesses using an automated welding process, AISI 1005 low-carbon steel as the parent metal, a gas metal arc welding (GMAW) digital power source with premixed shielding gas, and a one-sided clamping technique. Comparison of the simulation and experimental results shows that three-dimensional thermo-elastic-plasticFEM canpredictWD.

II. Simulationsand Experiments

Here, we consider the deformation of a structure comprisingtwo perpendicular pipes that are connected by welding. The pipe positions in the welding process are shown in Fig. 1; welding is used to connect a base pipe with a branch pipe. The base pipe is 200-mm long with a diameter of 60 mm,and the branch pipe is 150-mmlong with a diameter of 50 mm. After the two pipes have been fitted together, the welding process takes place as shown in Fig. 2. The simulations and experimentsinvolved pipes with thicknesses of 2.5, 3.2, 4.0, and 5.2 mm. The material parameters of the pipesused in the simulationsarethe same as for the AISI 1005 steel used in the experiments.

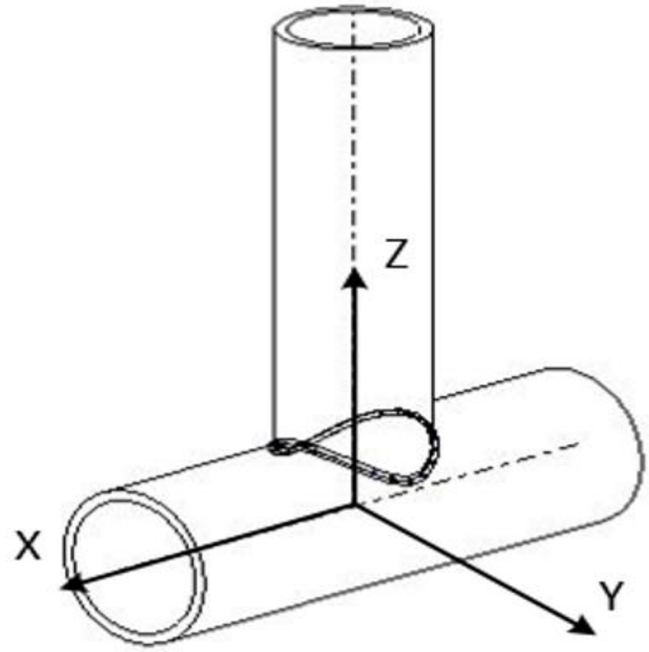

Figure 1. Simulation model.

The welding parametersfollow the AWS standard. In preparation, for each pipe thickness, two pipes were machined for assembly and then joined by point welds. For the simulations, we constructed a computer-aided design model as in Fig. 1. We exported this model to ANSYS inInitialGraphics Exchange Specification format, where it was converted into a meshing model with a proper mesh.To improve the simulation accuracy while managing the time it took, we refined the mesh locally at the welding area.Then, we sent the meshing model combined with the welding parameters to the ANSYS solution module to analyze the welding process in relation to the temperature distribution, deformation, and residual stress of the whole welded structure.

In recent years, thethermalanalysisisquiteacomplexphenomenonassociated with GMAW.The weld-pool shape isinfluenced greatly by the weld metal transfer modeandthecorrespondingfluidflowdynamics[9].Inthe FEM of GMAW, the most widely used double-heat-source model is that by Goldak et al. [8].Hence, we used this model toanalyzethe pipe deformation and residual stress.In the simulations and experiments, we evaluated the pipe deformation as shown in Fig. 2. To assess the influence of pipe thickness on the deformation of the structure, we used pipes with four different thicknesses. In the experiments, after finishing the welding process, we left the structure to cool down to room temperature. Then, we measured the deformation along the Z-axis, as shown in Fig. 2. For each pipe thickness, we operated the welding process with 10 parts and then calculated the averagedeformation for comparingwith the simulations. For both the simulations and experiments, the following welding parameterswere used: current of 90 A, voltage of 80 V, and welding speed of 3.2 mm/s.

Table 1. Deformation results(pipe thickness = 2.5 mm).

Simulation and experimental results																				
Distance (mm)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
Experiment	1.42	1.52	1.65	1.72	2.05	2.18	2.32	2.45	2.53	2.62	2.75	2.84	2.98	3.05	3.11	3.21	3.3	3.41	3.52	3.54
Simulation	1.27	1.61	1.65	1.87	2.01	2.15	2.25	2.38	2.45	2.58	2.69	2.78	2.92	3.01	3.09	3.25	3.41	3.52	3.61	3.68

Table 2. Deformationresults(pipe thickness = 3.2 mm).

Simulation and experimental results																				
Distance (mm)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
Experiment	0.74	0.86	0.98	1.02	1.08	1.14	1.25	1.28	1.35	1.47	1.52	1.61	1.73	1.85	1.98	2.04	2.15	2.32	2.58	2.7
Simulation	0.98	1.05	1.09	1.12	1.2	1.25	1.37	1.41	1.48	1.52	1.67	1.82	1.95	1.98	2.07	2.15	2.27	2.29	2.3	2.32

Table 3. Deformation results(pipe thickness = 4.0 mm).

Simulation and experimental results																				
Distance (mm)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
Experiment	0.35	0.35	0.48	0.48	0.52	0.65	0.65	0.68	0.72	0.78	0.82	0.85	0.93	0.96	1.02	1.15	1.22	1.32	1.45	1.62
Simulation	0.45	0.47	0.51	0.56	0.61	0.63	0.72	0.81	0.87	0.89	0.93	0.97	1.02	1.15	1.28	1.45	1.52	1.64	1.72	1.78

Table 4. Deformation results (pipe thickness = 5.2 mm).

Simulation and experimental results																				
Distance (mm)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
Experiment	0.31	0.31	0.32	0.35	0.46	0.46	0.48	0.57	0.57	0.62	0.68	0.72	0.75	0.83	0.85	0.92	0.95	0.98	1.02	1.05
Simulation	0.27	0.38	0.49	0.51	0.58	0.61	0.67	0.69	0.72	0.78	0.83	0.85	0.92	0.95	0.98	1.06	1.13	1.15	1.18	1.2

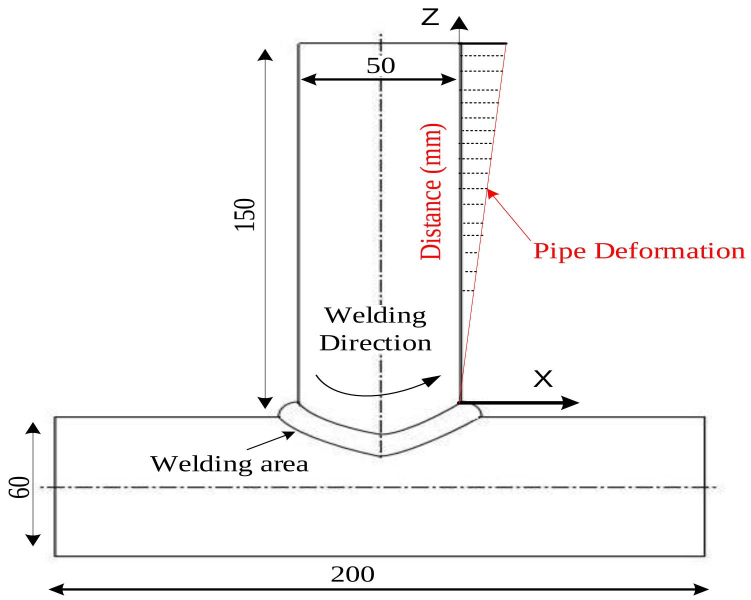

Figure 2. Location for observing the WD.

III. Results and Discussion

The resultsfor the pipe deformationarecollated in Tables 1–4 and compared in Figs. 3 and 4. Based on these results, it is clearthat the thinner pipes(2.5 and 3.0 mm) experiencedlarger deformations than didthethicker ones (4.0 and 5.2 mm). In addition, the maximum deformation occurred at the highest point of the branch pipe. Thus, with thinner pipes, the designer must have the solution for fitting the pipe after in the welding process. According to the simulation results, with the branch pipe and the welding structure as in Fig. 1 and 2, the maximumdeformationswere 3.53 mm, 2.32 mm, 1.78 mm, and 1.30 mmfor pipe thicknesses of 2.5 mm, 3.2 mm, 4.0 mm, and 5.2 mm, respectively. By contrast, the highest stress was located at the welding area because that is where the highest temperature(Fig. 3) in the welding process. Hence, this location should be designed with a higher safety margin than for other locations. A common and efficient way to reduce the residual stress in thinner pipes is to reduce the welding current. This method could also decrease the deformation because the heat transfer to the welding pool would be lower. However, the welding quality tends to suffer if the current is too low. The simulations also show the influence of pipe thickness on the residual stress when the welding was operated with the same parameters as in Table 3. When the pipe thickness was increased from 2.5 to 5.2 mm, the maximum residual stress decreased from 677 to 498 MPa.

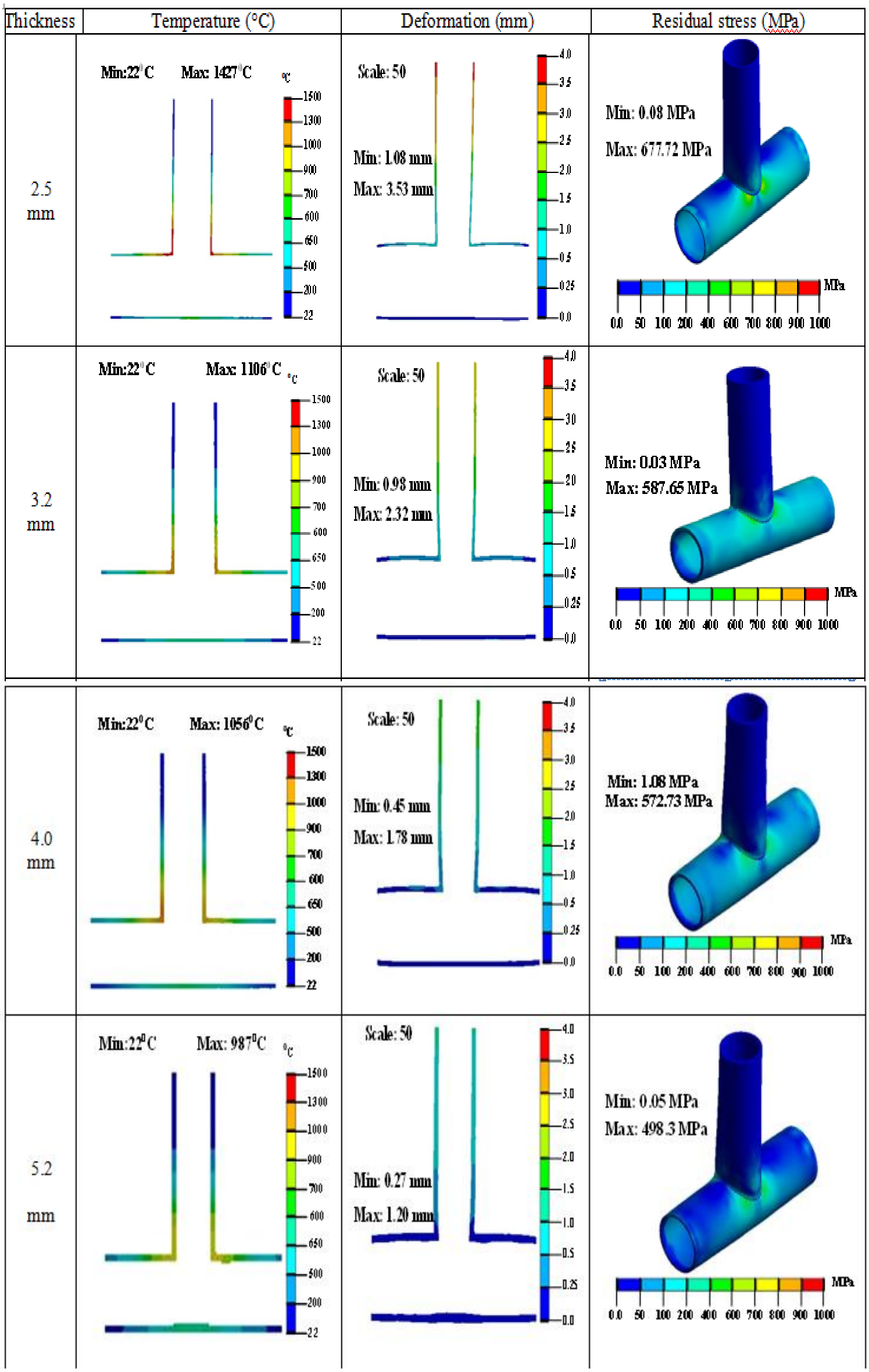

Figure 3. Simulation results at the end of a welding cycle.

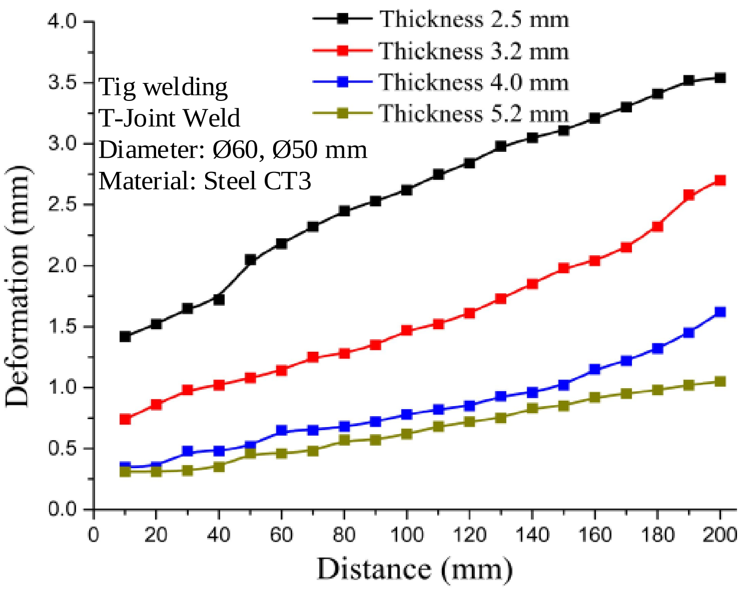

Figure 4. Comparison of pipe deformationsfor different pipe thicknesses.

To assess the simulation accuracy, we conducted experiments where we welded pipes with four different thicknessesandrepeated the welding process 10 times for each thickness.Then, we took the average measured deformation and compared it with the corresponding simulation result. The results are shown in Figs. 4–7 (seeTables 1–4 for the data). Based on these results, we conclude that the simulations and experimentsare in excellent agreement. The differences between the simulations and experiments are due to the heat transfer and conductivity of the pipe material. In the simulations, these properties were assumedto be perfectcondition,butthe actual behavior in the experiments could not exactly match the simulations.The rate of heat transfer in the experiments was lower than that for a perfect material, so the pipe was hotter at the end of a welding cycle than it was in the simulations. This is the main reason for the different deformations between the simulations and experiments.

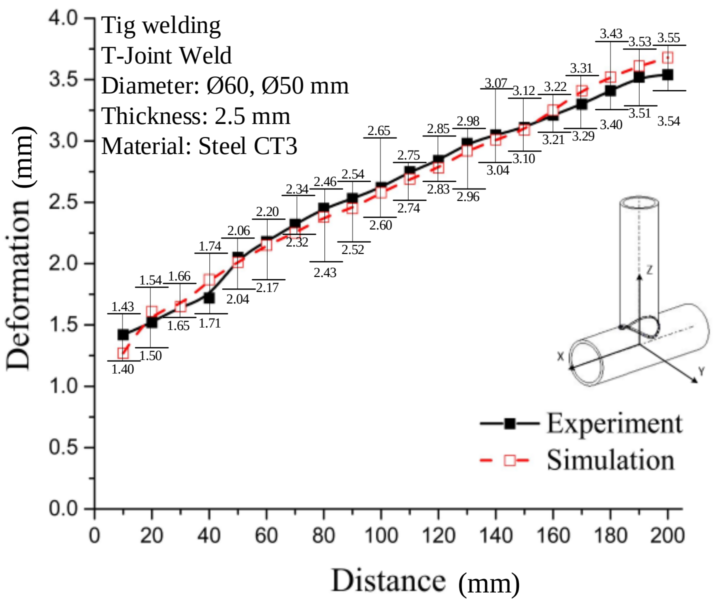

Figure 5. Deformationof a 2.5-mm-thick pipe.

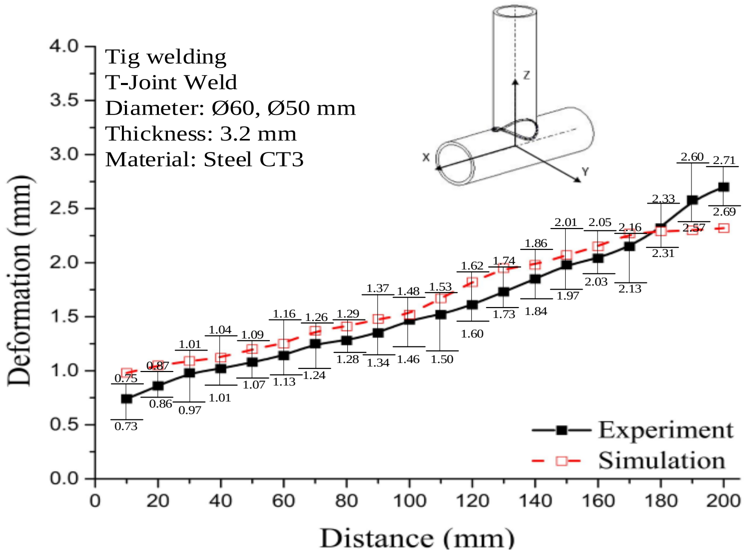

Figure 6. Deformation of a 3.2-mm-thick pipe.

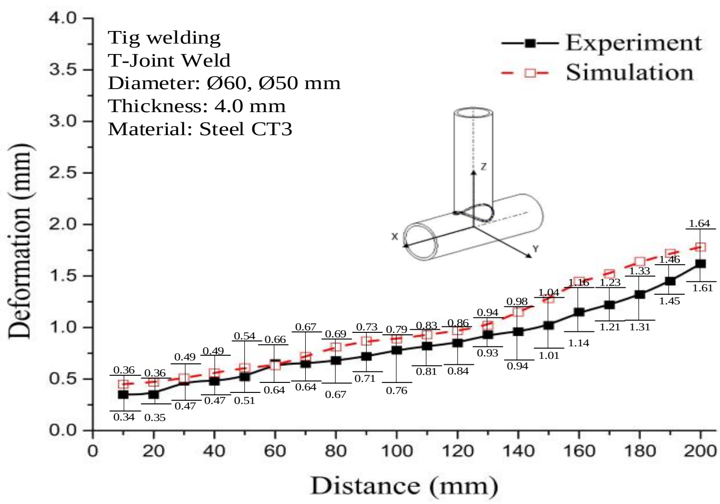

Figure 7. Deformation of a 4.0-mm-thick pipe.

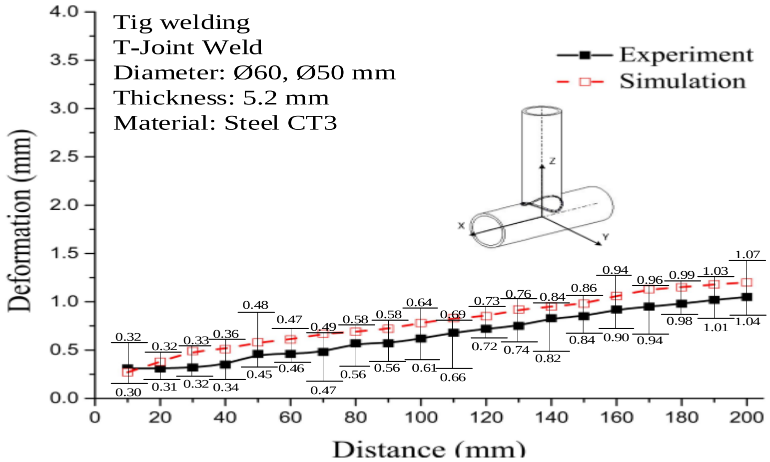

Figure 8. Deformation of 5.2-mm-thick pipe.

IV. Conclusions

In this study, the method of linear elastic shrinkageusing relatively new FEM software developed by ANSYSInc.was employed to simulate the welding process and to predict the welding distortion of pipeswithdifferent thickness. For verification purposes, a series of experiments wereperformed using a fully automated welding system with a GMAW power source. The results show that with the same welding parameters, a thinner pipe will experience a larger deformation, with the largestpipedeformation located farthest from the welding area. Simulations were used to evaluate the temperature distribution and the residual stress. In the welding process, the highest temperatureat the welding location, which means that the highest residual stress was also located there. The thinner the pipe, the higher the residual stress would be. The simulation results agree well with the experimental results, which means that our method could be used to predictpipe deformation due to welding.

References

[1]. L. Gannon, Y. Liu, N. Pegg, and M. Smith, Effect of welding sequence on residual stress and distortion in flat-bar stiffened plates, Marine Structures, 23, 2010, 385 – 404.

[2]. L. E. Lindgren, Numerical modelling of welding, Computer Methods Applied Mechanics and Engineering, 195, 2006, 6710–6736.

[3]. R. Wang, J. Zhang, H. Serizawa, and H. Murakawa, Study of welding inherent deformations in thin plates based on finite element analysis using interactive substructure method, Materials and Design, 30, 2009, 3474 – 3481.

[4]. L. Shixiong, J. Song, H. Wang, and S. Yang, Temperature field and flow field during tungsten inert gas bead welding of copper alloy onto steel, Materials Science and Engineering A, 499, 2009, 347 – 351.

[5]. Z.B. Dong and Y.H. Wei, Three-dimensional modeling weld solidification cracks in multipass welding, Theoretical and Applied Fracture Mechanics, 46, 2006, 156–165.

[6]. G. Zhou, X. Liu, C. Jin, J. Yang, and H. Fang, Welding deformation controlling of aluminum-alloy thin plate by two-direction pre-stress method, Materials Science and Engineering A, 499, 2009, 147 – 152.

[7]. P. Zeng, Y. Gao, and L.P. Lei, Welding process simulation under varying temperatures and constraints, Materials Science and Engineering A, 499, 2009, 287 – 292.

[8]. J. Goldak, A. Chakravarti, and M. Bibby, A new finite element model for welding heat source, InternationalJournal Metallurgical and Materials Transactions B, 15, 1984, 299 - 305.

International Journal of Engineering Science Invention(IJESI) is UGC approved Journal with Sl. No. 3822, Journal no. 43302.

Pham Son Minh Deformation of T-Connected Pipes DuetoWelding Process." International Journal of Engineering Science Invention(IJESI), vol. 6, no. 11, 2017, pp. 17-23.