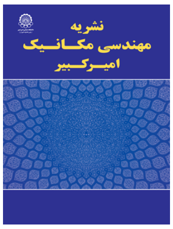

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Investigation of the effect of welding path on residual stresses and deformations in peripheral welding of steel pipe

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ABSTRACT: In this paper, the effective factors in the welding process and its effects such as residual stresses in the peripheral welding process of a pipe have been investigated using Abaqus software. The analysis was performed in two stages, thermal and mechanical. First, in thermal analysis, the temperature distribution of the welding process was obtained, and then the obtained temperature field was used as a load in mechanical analysis to obtain the distribution of residual stresses and deformations. The effect of different parameters such as welding speed, heat input, and sequence of welding path on residual stress values and deformations were investigated. Results showed that with a 50% increase in electrode speed, tensile and compressive stresses on the outer surface of the pipe showed an increase of 43.47 and 15.15%, respectively. Also, a 20% increase in heat input led to a reduction of 2.6 and 18.18% in tensile and compressive stresses on the outer surface of the pipe. Also in this paper, an optimal path for peripheral welding of pipes is presented.

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1- Introduction

Welding processes are one of the most common methods for connecting parts in various industries. Due to the non-uniform temperature change that occurs during welding, severe distortions and residual stresses occur in the welded parts [1]. Distortions cause residual stresses in parts that the presence of residual stresses, if they are tensile, significantly reduce their life [2, 3].

In this study, the residual stresses and distortions due to peripheral welding of a steel pipe were investigated and after examining various parameters such as welding speed, heat input and sequence of different path in each passes, an optimal model for reducing residual stresses and distortions has been presented, which has not been done in any research so far.

2- Preparing the Model

The considered model is a pipe with an outer diameter of 114 mm, an inner diameter of 108 mm and a thickness of 6 mm, which is shown in Fig. 1.

The pipe is made of SUS 304 stainless steel. The thermal and mechanical properties corresponding to the temperature of this metal are extracted from reference [4]. The speed of the electrode is 80 mm/min, the voltage in each of the welding passes is 9.5 V and the intensity of the ampere in the first pass is 140 and in the second pass is 160 A. Fig. 2 shows the number and arrangement of passes.

Simulation was performed non-coupled in two parts: thermal and mechanical analysis. The DC3D8 element, which is a hexagonal element with a degree of temperature freedom, was used for thermal analysis. Also, an element with stress release degrees (C3D8R element) was used for mechanical analysis. Six different modes were considered in two passes for pipes with geometric characteristics expressed at the beginning of the section. In this way, the pipe is first divided into 4 equal quarters and each quarter is considered a path. Depending on the speed of the electrode and the diameter of the tube, it takes 9 seconds to weld the entire tube. The cooling time between each path in the first pass is set to zero, but the cooling time between the first pass and the start of the second pass was set at 9 seconds. Also, the paths in the second pass were considered the same as the paths in the first pass, and the cooling time between the paths of the second pass was considered zero, and after the completion of the second pass, 9 seconds of cooling time was considered. Fig. 3 shows all the conditions considered for different paths and directions of peripheral pipe welding.

3- Results and Discussion

For the accuracy of the results, the conditions used were considered the same as the conditions used in [4] and after thermal and mechanical analysis, the results were compared with the experimental results. Fig. 4 shows the contours related to the axial residual stresses after the completion of the welding process in the six modes.

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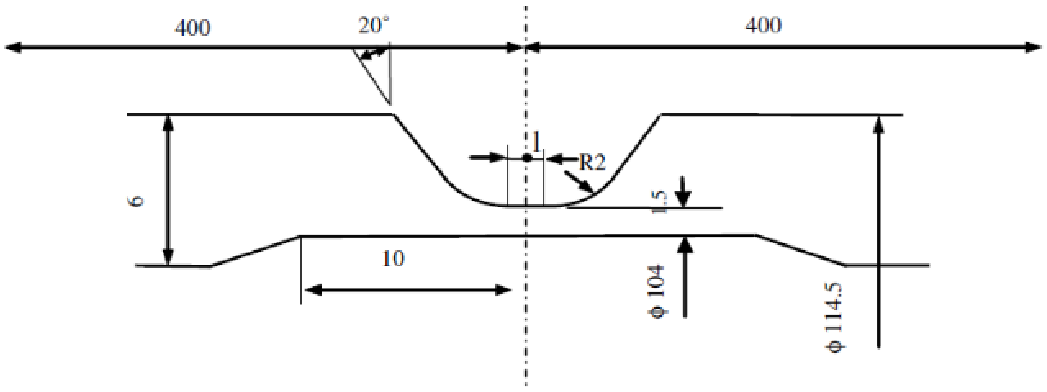

Fig. 1. Geometric dimensions of the desired pipe and weld line [4].

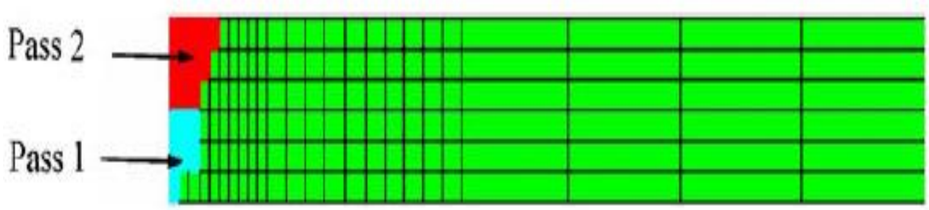

Fig. 2. Number and sequence of weld passes.

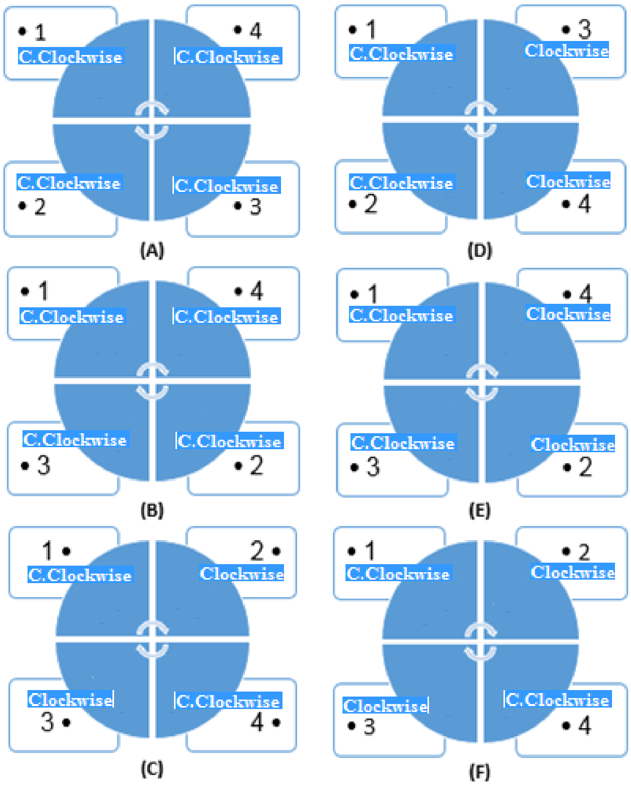

Fig. 3 . Six different modes of the welding.

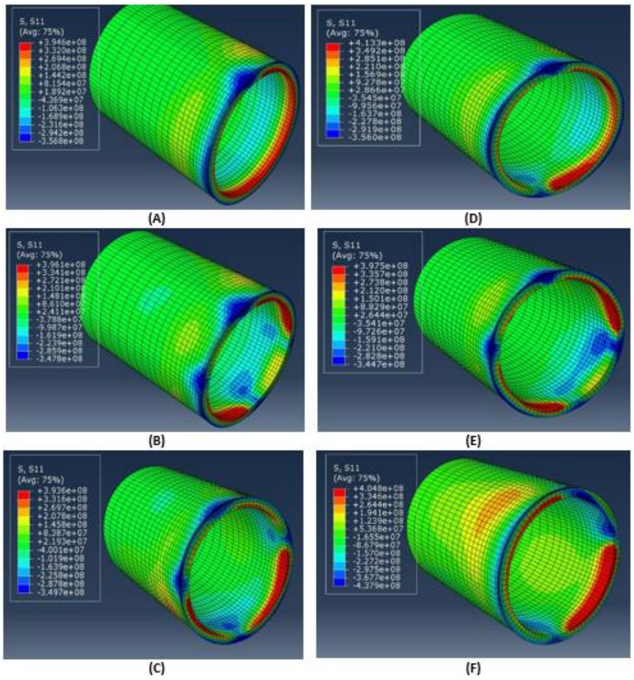

Fig. 4. Axial stress distributions of the welded pipe in different modes.

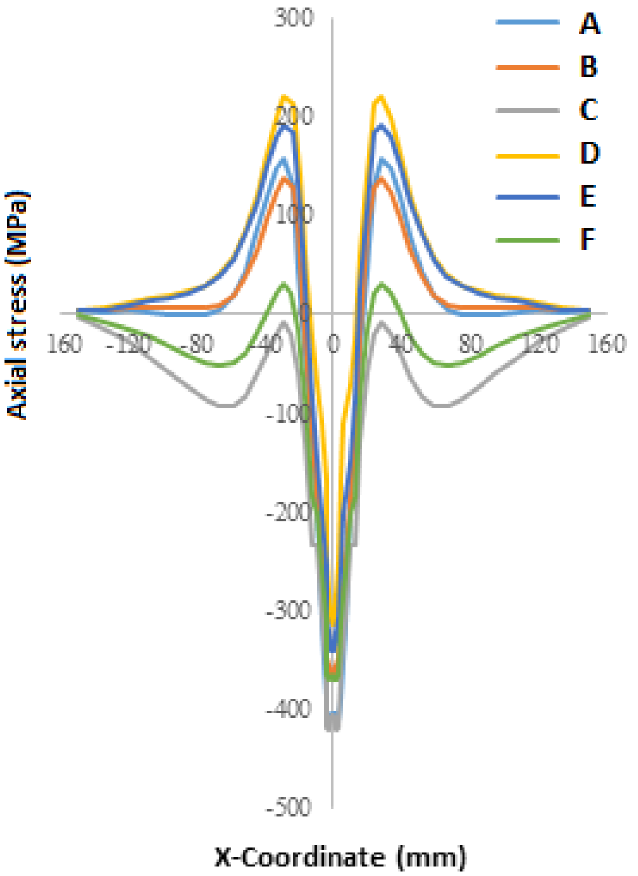

Fig. 5. Axial stress distributions on the outside surface in different modes.

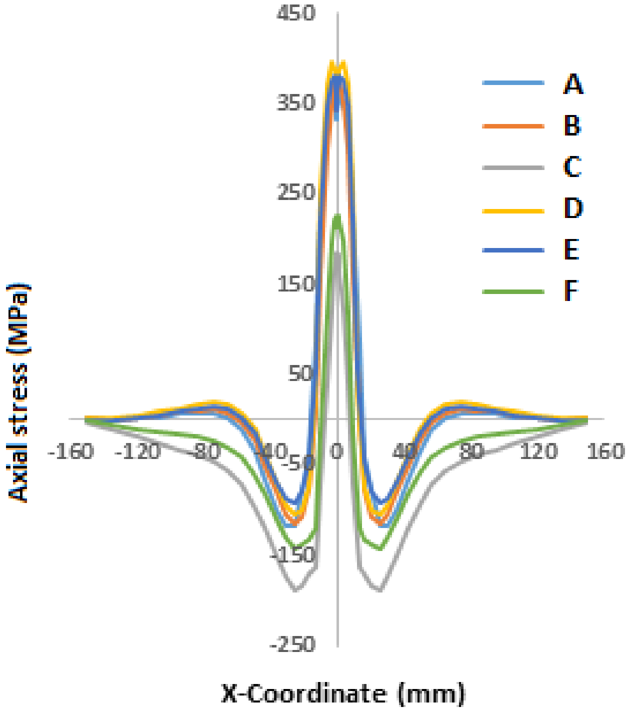

Fig. 6. Axial stress distributions on the inside surface in different modes.

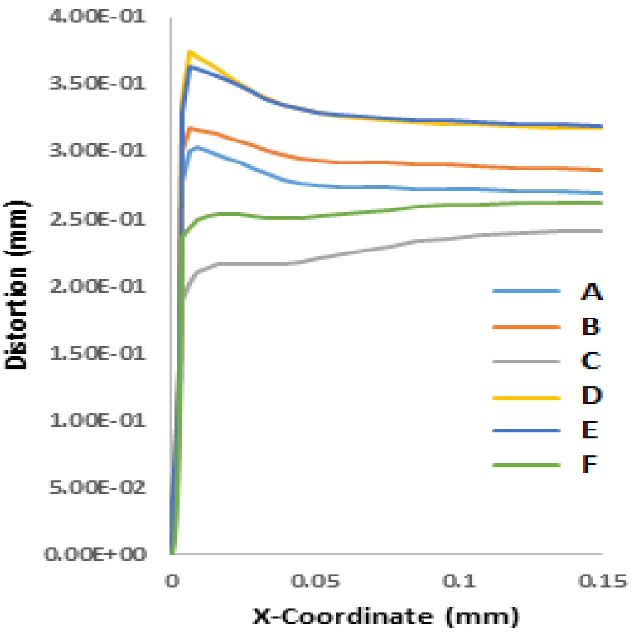

Fig. 7. Comparison of longitudinal distortion on the inside surface in different modes.

Figs. 5 to 7 show diagrams for comparing the various residual stresses and distortions created in the six modes considered.

Considering the different modes of peripheral welding of the pipe, it was found that the axial stress on the outer surface of the pipe in C mode has an optimal value so that all tensile stresses were converted to compressive stress and no tensile stress is created on the outer surface of the pipe. This is while the amount of compressive stress has not changed much compared to the reference state [4].

The axial stress on the inner surface in C mode has the lowest value and while compared to the reference mode [4], tensile and compressive stresses were reduced by 55% and 49.3%, respectively. Also, by comparing the distortion diagrams of different states, it is determined that mode C has the least distortion.

4- Conclusions

In this paper, the residual stresses and distortions due to peripheral welding of a steel pipe are investigated. After examining various parameters such as welding speed, heat input and sequence of different paths, an optimal model for reducing residual stresses and distortions is presented. The most important results are:

1- By comparing the simulation and experimental results, it was found that there is a good agreement between the results and the results of the performed model are reliable.

2- With a 50% increase in the speed of the electrode, the axial tensile and compressive stresses located on the inner and outer surfaces of the tube decreased, but the tensile and compressive stresses on the outer surface of the tube showed a significant increase.

3- The study of the effect of heat input showed that with a 20% increase in heat input:

A) Axial tensile and compressive stresses on the outer surface of the pipe increased and decreased, respectively, and the opposite was observed on the inner surface of the pipe.

B) Tensile and environmental compressive stresses on the outer and inner surfaces of the pipe were reduced.

4- According to the comparison of residual stress and distortion diagrams of different considered modes, it was found that C mode had the lowest amount of residual stress and distortion, so it is introduced as the optimal mode for peripheral welding of pipes.

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