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Sensitivity Analysis for Residual Stress on DVI Nozzle Welding Joint

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1. Introduction

It is well known that a lot of residual stresses are occurred after welding process due to the high gradient of thermal and mechanical history at heat affected zone during welding process.

Those residual stresses produced by the welding process, especially the tensile residual stresses, have a not negligible effect on the material strength, on the fatigue and corrosion crack.

For this reason, it is important that some knowledge of the internal stress state can be deduced either from measurements or from modeling predictions.

In this study, the residual stresses after multi-pass welding process for DVI nozzle welding joint have been evaluated by a numerical simulation method.

2. Methods and Results

Numerical simulation of residual stresses and distortions due to welding needs to accurately take account of the interactions between heat transfer, metallurgical transformations and mechanical fields. The phenomena involved in the heat input such as arc, material/laser interactions as well as fluid dynamics in the weld pool are not accurately described.

From the thermo-mechanical point of view, the heat input can be seen as a volumetric or surface energy distribution, and the fluid flow effect, which leads to homogenize the temperature in the molten area, can be simply taken into account by increasing the thermal conductivity over the fusion temperature.

The different phenomena involved and their couplings are given in Fig.1

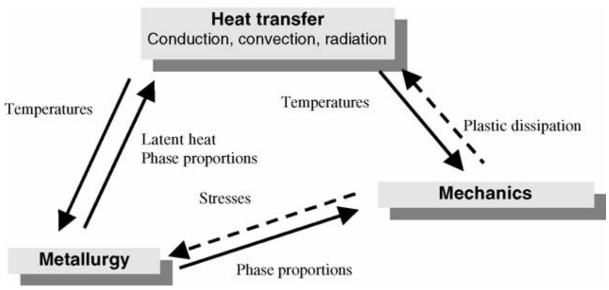


Figure 1. Physical phenomena involved and their couplings.

In this study, the thermal, metallurgical and mechanical analyses for the multi-pass welding joint were performed with Sysweld's Multi-pass Advisor technology.

2.1 Modeling of Materials

DVI Nozzle welding joint is consisted of four components which are Base shell, Buttering Area, Joint Area, Safe-end.

A schematic drawing of DVI Nozzle welding joints is shown in Figure. 2 and the names of materials for each component are listed in Table. 1.

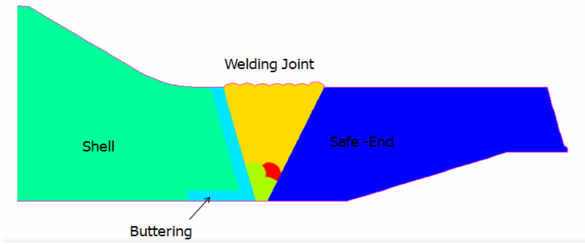


Figure 2. A schematic design of DVI Nozzle welding joint

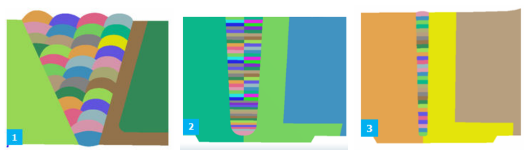
<table>
<tr><th colspan="2">Components</th><th>Material Name</th></tr>
<tr><td colspan="2">Shell</td><td>SA-508</td></tr>
<tr><td colspan="2">Buttering Area</td><td>SB-166</td></tr>
<tr><td colspan="2">Safe-End</td><td>SA-182</td></tr>
<tr><td rowspan="3">Welding Joint</td><td>Already deposited</td><td>SB-166</td></tr>
<tr><td>Deposit</td><td>SB-166 + Bead Material</td></tr>
<tr><td>Not yet deposited</td><td>Dummy Weld Material</td></tr>
</table>

Table 1. Materials lists of components

In case of the Welding Joint, the materials are needed to be updated according to the welding process and those materials are managed automatically with Multi-pass Welding Advisor.

2.2 Modeling of Welding Joint

In this study, three different joint angles (40^o, 6^o, 2^o) are modeled and FE mesh was created. Fig. 3 shows the different joint angles and bead shapes for DVI nozzle.

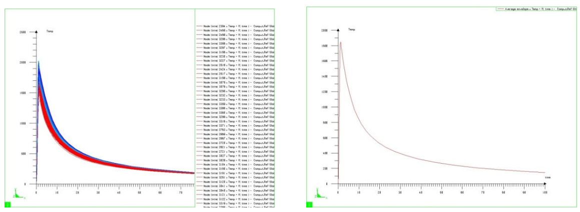


a) 40^o b) 6^o c) 2^o

Figure 3. Different Joint Angles and bead shapes for DVI Nozzle

2.3 Modeling of Heat Source and Thermal Cycle

The heat source for each Joint Angle was defined considering the welding process for DVI Nozzle. A GTAW welding process conditions were used and the heat source was fitted to meet the real welding process conditions using Heat Input Fitting Tool.
2D transient thermal calculation was performed using the fitted heat source on one of the beads. And thermal history of each node on the bead area was plotted then averaged.



a)Extracted thermal cycle   b)Averaged thermal cycle

Figure 4 Extracted and averaged thermal cycle from 2D Transient thermal calculation

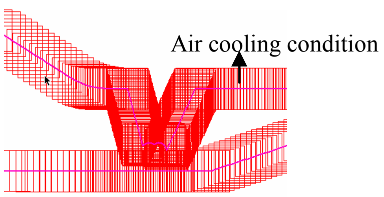
This extracted thermal cycle was applied as a thermal loading to each bead according to the welding process.

2.4 Cooling conditions

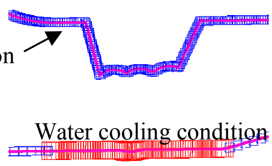
Two kinds of cooling process during welding process were modeled in this study.

1) Air cooling condition
2) Water cooling condition

The air cooling condition was applied to the exterior skin of the component as a standard cooling process and water cooling condition was applied to the root area of welding joint as a proposed cooling process to decrease residual stresses during welding. Figure 5 shows applied cooling conditions in this study.



a) Standard cooling condition



b) Water cooling condition

Figure 5. Different cooling conditions for DVI Nozzle

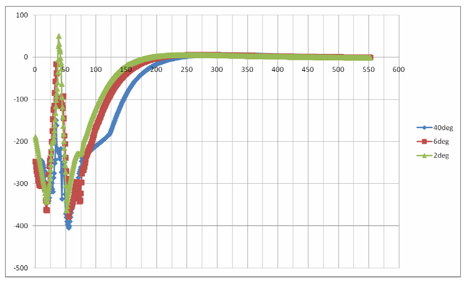
2.5 Analysis Results

2D transient thermal, metallurgical and mechanical calculation was performed for multi-pass welding process and the results of different welding joint angles, different cooling conditions were evaluated.

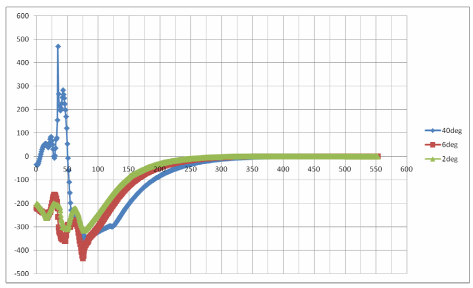
1) Results of different welding joint angles

Fig. 6 shows hoop and axial stress results at the inner surface of DVI Nozzle for each joint angle.

As a joint angle decreased, the hoop stress at the inner surface is moved toward to the tensile residual stress. But, in case of axial stress, the negative residual stresses were occurred at the inner surface when the joint angle was decreased.



a) Hoop Stress comparison



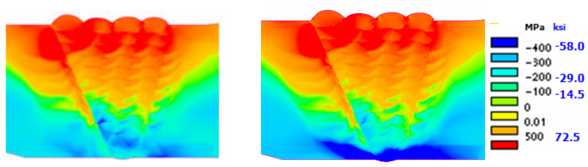
b) Axial Stress comparison

Figure 6. Residual Stress comparison results at the inner surface

1) Results of different cooling conditions

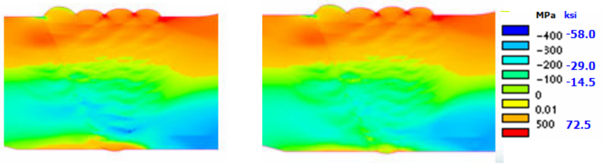
The results of standard cooling condition and water cooling condition were compared to evaluate the effect of a high cooling rate.

As shown in figure 7 and 8, when we applied a high cooling rate on the root area of welding joint, the residual stresses are shifted to negative value which means that we can expect more compressive residual stresses at the inner surface with high cooling rate.



a) Standard Cooling   b) Water Cooling

Figure 7. Hoop stress results of different cooling rate



a) Standard Cooling   b) Water Cooling

Figure 8. Axial stress results of different cooling rate

3. Conclusion

To evaluate the effect of different joint angles and different cooling rate for multi-pass welding joint of DVI Nozzle, 2D transient multi-pass simulations were performed. And the results from various conditions showed that

1) When the joint angle was decreased, tensile hoop stress region was increased toward inner surface.
2) When the joint angle was decreased, tensile axial stress region was decreased toward inner surface.
3) When a water cooling condition was applied to the inner surface, both of the hoop and axial residual stress wax decreased at the inner surface, but the efficiency was lowered in case of the axial stress.

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