Welding residual stress and distortion in ZS100 motorcycle rear fork welded joints

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Abstract. Finite element (FE) method was utilized to analyze the welding temperature field, stress and distortion in a ZS100 motorcycle rear fork. The FE models were simplified due to symmetry of the structure. Simulation results show that temperature distributions, residual stress variation and distortion in the structure are complex and related to welding current. Magnitudes of residual stress occur in HAZ and weld metal for components of side tube-connecting tube and side tube-axle tube. Increasing welding current can result in higher residual stress level and post-welding distortion. Therefore, relative small welding current is preferred for the sake of reduce welding stress and distortion.

1. Introduction

Motorcycle rear fork, usually made by welding, is an important component for the installation of rear wheel, shock absorber, brake and sprocket. It is mainly composed of two side tubes, connecting tube, axle tube, reinforcement plate, and linings, etc. Since its welding process is complex and the welded seams are concentrated, large welding residual stress and deformation can easily occur due to improper welding specification and procedures. Consequently integral welding quality and safety factor of the motorcycle can be seriously reduced [1-3]. Therefore, welding parameters and welding sequences are should be optimized and carefully chosen.

Generally, factors which affect welding residual stress and deformation include: welding method, welding parameters (welding current, arc voltage, welding speed, etc.), number of welded beads, welding sequences, clamping conditions, structure geometries and material properties [4-6]. Among these factors, welding parameters and sequences are of great importance and can be controlled easily. In this investigation, welding process of ZS110 motorcycle rear fork was simulated using different welding parameters. Influence of welding parameters on welding temperature field, residual stress and strain was analyzed to obtain an optimal welding procedure.

2. Experimental

The base metal of ZS110 motorcycle rear fork is high strength low alloy (HSLA) S355 steel. The chemical composition of used S355 steel is presented in Table 1. The rear fork was joined using gas metal arc welding (GMAW) with an external shielding gas of CO_2. The filler wire used in the experiment is ER50-6 with a diameter of 1.2 mm. The welding parameters for joining of side tube and connecting tube (Part 1) consist of 20V welding voltage, 5 mm/s welding speed, and three welding current levels (210A, 225A, and 235 A). The weld seams in Part 1 were welded in the same direction simultaneously. The welding parameters for joining side tube and axle tube (Part 2) in the end were the same as that used for joining of side tube and connecting tube. Straight weld seams in Part 2 were welded first applying a simultaneous same-direction-welding technique, and welding of circumferential weld seams were started 20 s later after welding of the straight weld seams.

Table 1. Chemical composition of the base metal (wt, %).

C	Si	Mn	S	P	Ni	Cr
0.15	0.35	1.30	0.003	0.010	0.010	0.018

3. Numerical procedure

The SolidWorks software was used for the modeling of a three dimensional (3D) solid model which is shown in Fig. 1. The Visual Mesh software was used for the meshing of the rear fork. In order to reduce the computational cost, only half of the rear fork was modeled due to symmetry. Since the side tube is long and its end is far from the weld seam, the model can be simplified into two parts which are shown in Fig. 2 and Fig. 3. A fine mesh with the edge size of 1.5 mm was used for the weld metal and heat affected zone (HAZ), while a coarse mesh with the edge size of 2.5 mm was used for metal distant from the welding zone. Models of the two parts contain 39200 meshes and 14320 meshes, respectively. The element birth and death technique was used to simulate the weld metal deposition with time. Initial temperature of the welding structures was set to be 20°C. A double ellipsoid heat source model was used to represent the heat input in the welding process. SYSWELD software was used to simulate the welding residual stress and distortion in the welded joints.

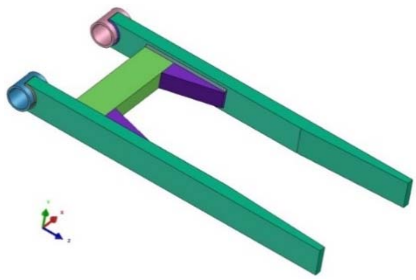


Figure 1. Solid model of the rear fork.

Figure 2. Assembly of side tube and connecting tube.

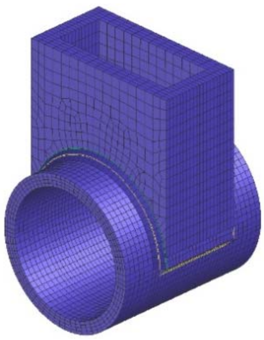
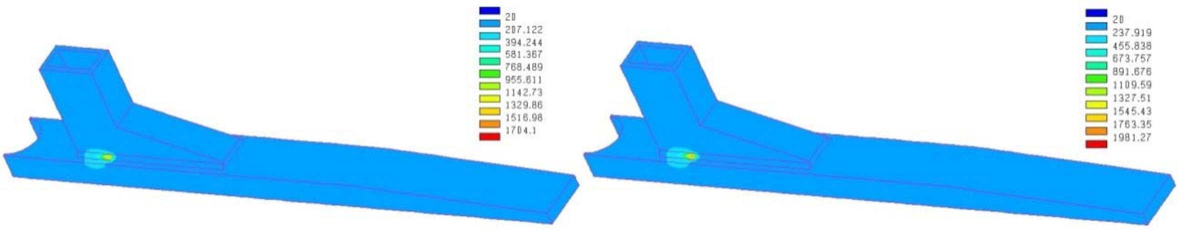


Figure 3. Assembly of the axle tube and side tube.

4. Results and discussion

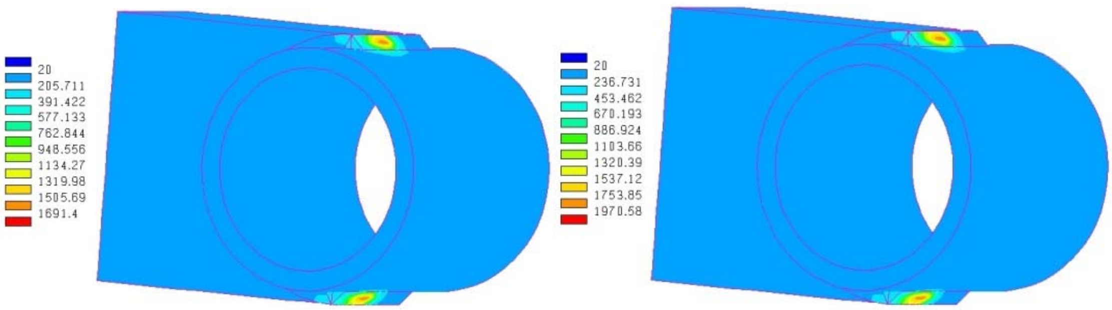
4.1. Temperature field

For the sake of illustration, temperature distributions with welding currents of 210A and 235A are displayed for part 1 and part 2 (Fig. 4 and Fig. 5). It is seen from Fig. 4 that with 210A welding current, the peak temperature in the welding process is about 1700 °C for Part 1. With high welding current of 235 A, the maximum temperature in the welding pool is higher and reaches 1981°C. It is also seen from Fig. 5 that the peak temperature in the welding process for Part 2 increases with welding current and the difference is 279 °C for the two current levels.



(a) (b)

Figure 4. Temperature distribution in the welding process for Part 1: (a) I=210A, (b) I=235A.

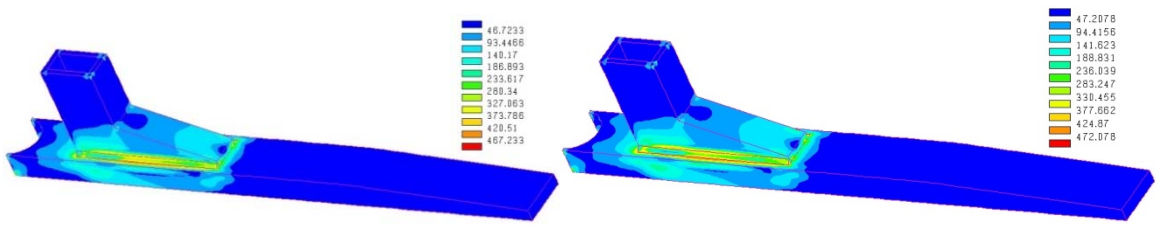


(a) (b)

Figure 5. Temperature distribution in the welding process for Part 2: (a) I=210A, (b) I=235A.

4.2. Stress distribution

Von Mises equivalent stress distributions after welding with welding currents of 210A and 235A are displayed for part 1 and part 2 (Fig. 6 and Fig. 7). High level residual stress mainly occurs in HAZ and the weld metal. It is found that with small welding current, residual stress peak level in Part 1 is relative low (467 MPa), while residual stress level reaches 472 MPa with 235A welding current.

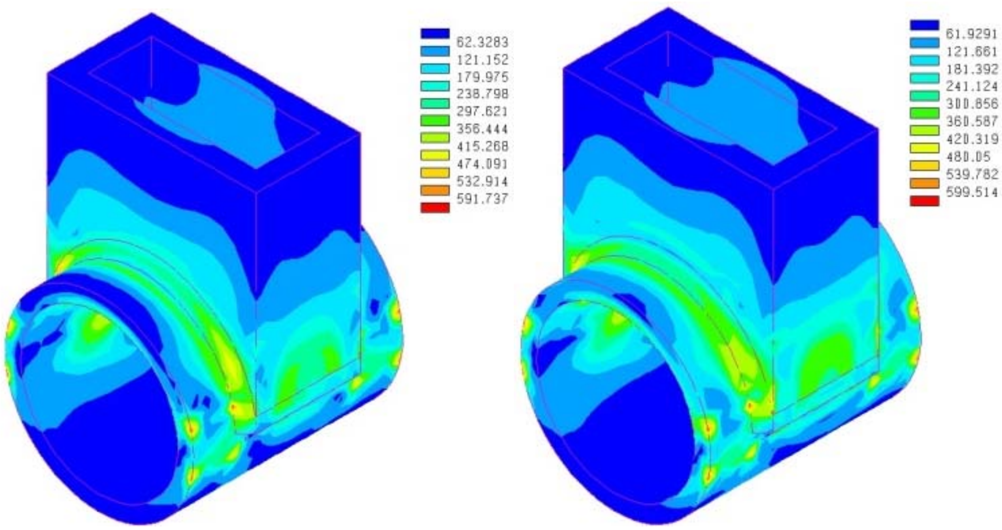


(a) (b)

Figure 6. Residual stress distribution for Part 1: (a) I=210A, (b) I=235A.

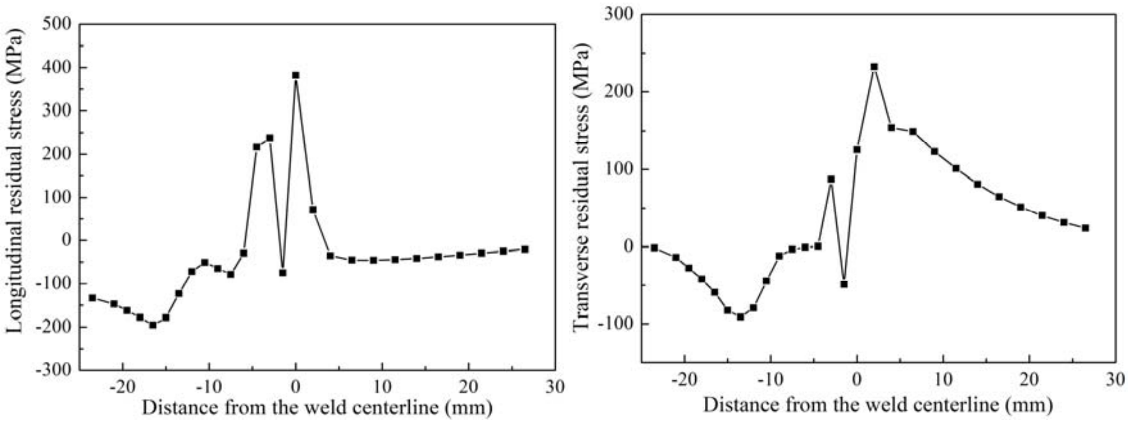
Fig. 8 shows longitudinal residual stress (σ_x) and transverse residual stress (σ_y) distribution along the width direction in Part 1 with welding current of 235A. It is found that compressive stress occurs in the weld centre for both σ_x and σ_y. However, high level tensile stress occurs in the HAZ for both σ_x and σ_y.

Longitudinal residual stress (σ_x) and transverse residual stress (σ_y) distribution along the width direction in Part 2 is presented in Fig. 9. For straight weld seams in Part 2, compressive stress appears in the weld centre and its magnitude is about 280 MPa for longitudinal stress. The maximum values of σ_x and σ_y occur in the vicinity of HAZ for straight weld seams. For circumferential weld seams, stress distributions on two sides of the weld seam are not symmetrical for σ_x and σ_y. Maximum peak values of compressive and tensile stress appear on two sides of the weld centreline for σ_x and σ_y. This phenomenon may relate to the structure geometry and the welding sequence characteristics.



(a) (b)

Figure 7. Residual stress distribution for Part 2: (a) I=210A, (b) I=235A.



(a) (b)

Figure 8. Residual stress distribution for Part 1: (a) σ_x, (b) σ_y.

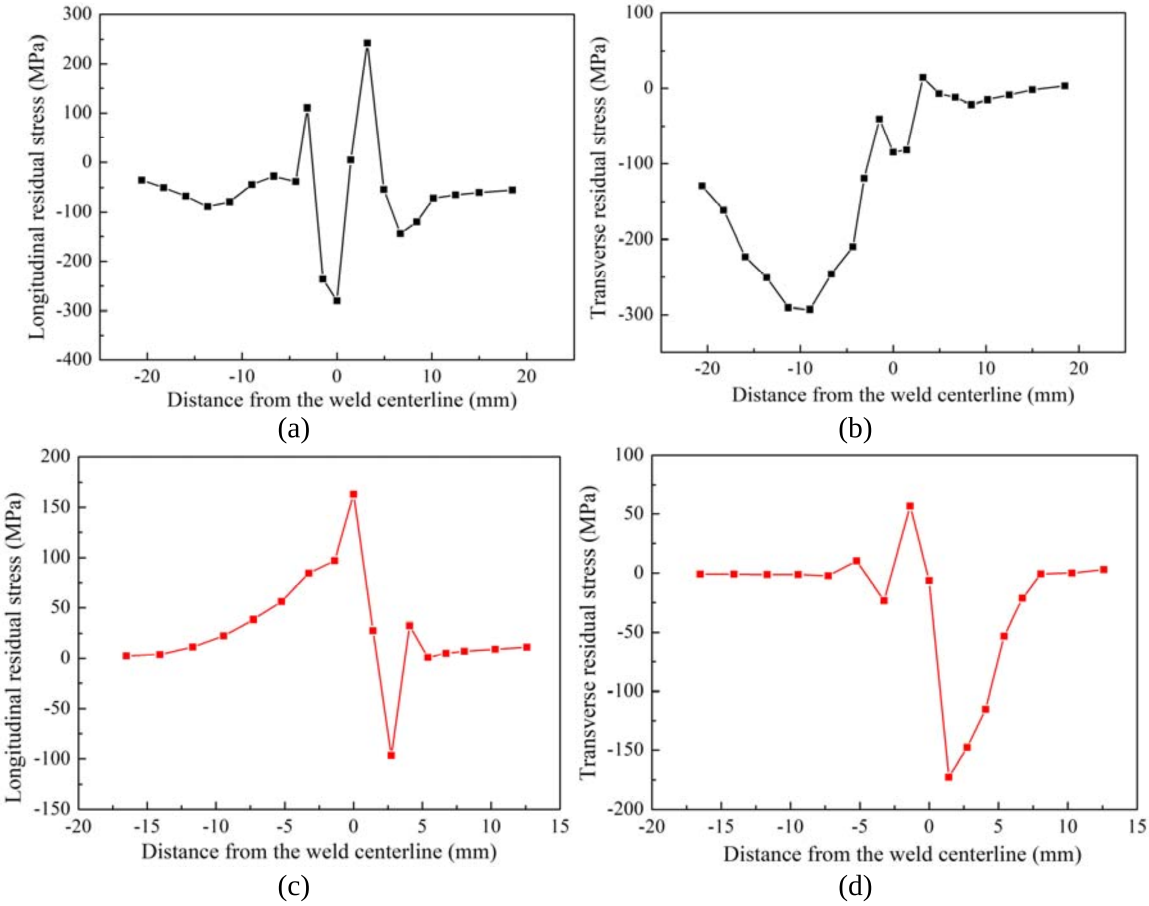
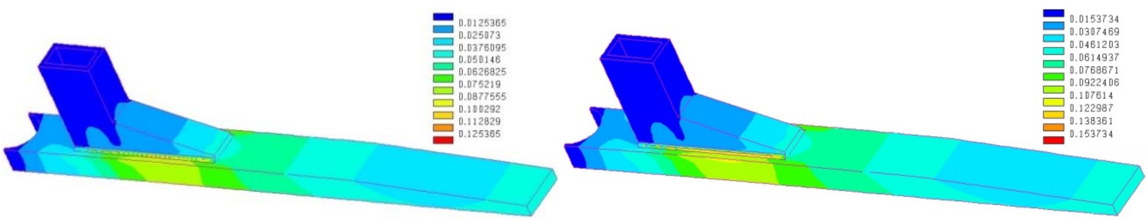


Figure 9. Residual stress distribution for Part 2: (a) σ_x (straight weld), (b) σ_y (straight weld), (c) σ_x (circumferential weld), (d) σ_y (circumferential weld).

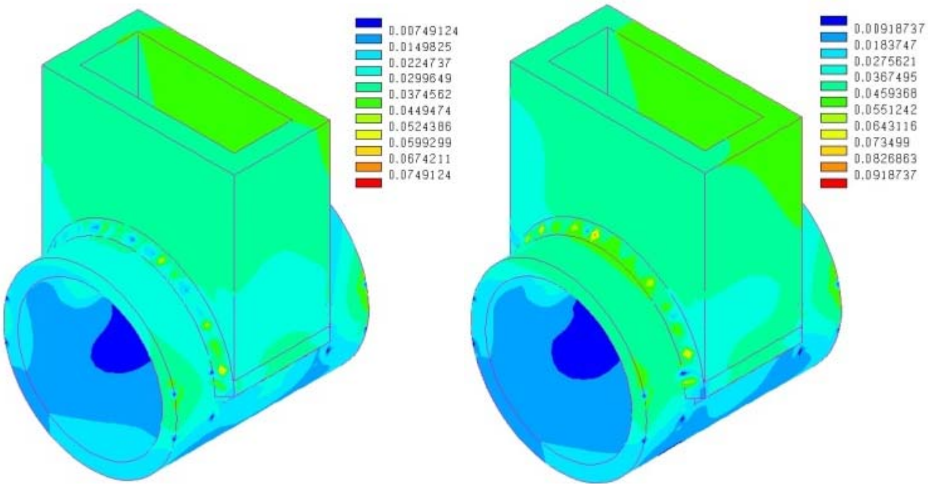
4.3. Distortion analysis

Welding-induced distortion in the workpiece after welding is shown in Fig. 10 and Fig. 11. The case of Part 1 shows a displacement of 0.138 mm with 210 A welding current, while a displacement of 0.169 mm occurs with 235 A welding current. For Part 2, 210 A welding current results in a displacement of 0.082 mm, while 235 A welding current results in a displacement of 0.101 mm. It is obviously that with increasing welding current, residual distortion increases in both Part 1 and Part 2.



(a) (b)

Figure 10. Residual displacement distribution for Part 1: (a) I=210A, (b) I=235A.



(a) (b)

Figure 11. Residual displacement distribution for Part 2: (a) I=210A, (b) I=235A.

5. Conclusion

Using SYSWELD software, 3D simplified models of ZS100 motorcycle rear fork were established. Temperature field, residual stress and distortion in the components were analyzed. Parametric study was carried out to evaluate the effect of welding current on welding temperature histories, stress distributions and residual distortion. It is found that with higher welding current, peak temperature in the welding pool increases in both Part 1 and Part 2. Residual stress level and distortion in the components increase slightly with increasing welding current. To control the residual stress level and reduce residual distortion in the rear fork, 210 a welding current is recommended in the present study.

Acknowledgments

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