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STUDIES ON DEFORMATION AND FRACTURE BEHAVIOUR OF WELDED PLATE FOR A SUPER STEEL

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ABSTRACT

In the present investigation, stress-strain field and fracture parameters as CTOD and J integral of practical overmatched welded plate made of a super steel SS400 is computed using MARC finite element program in 3D condition. The results of the computation show that mechanical heterogeneity has obvious influence on the shape and size of plastic zone. CTOD and J integral of the welded plate are smaller than those of the whole base metal plate in the same tension. Thus, the anti-fracture property of overmatched welded plate is better than that of the whole base metal plate.

KEY WORDS

Super steel SS400, Welded joint, Full yield, CTOD, J integral

INTRODUCTION

Welded joints is a mechanical heterogeneous body which is composed of base metal, heat affected zone (HAZ) and weld metal. Mechanical heterogeneity has important influence on the fracture behavior of structures. In most of studies, welded joints are assumed to be two parts of base metal and weld metal [1,2]. However, for practical welded joints HAZ is often weaker and is sensitive to defects. Therefore, the effect of HAZ is obvious, particularly for the thin plate. Super steel is newly developed steel material with super high strength, super fine grain and super clean micro-structure. The influence of welding on fracture behavior gain special attention.

Soete[3] suggests that allowed defect size can be determined on a basis of strain in large mark distance of wide plate in tension. That is, if a specimen containing a notch is under the action of perpendicular stress and the specimen is under condition of full yield or the whole elongation in the marked distance is up to 1~2%, this type of defect is allowed. Such an assessment standard for the acceptance of flaw in wide plate test is simple and suitable for engineering practice, for it is with a view to whole plasticity of specimen rather than local deformation. Experiments[4] show that overmatching welded joints is apt to attain full yield than homogeneous base metal, so its limit crack size is large and its anti-fracture behavior is enhanced.

In the present investigation, stress-strain field and fracture parameters as CTOD and J integral of practical overmatched welded plate made of super steel SS400 is computed. According to the full yield criterion, overmatched welded joint has better anti-fracture behavior than homogeneous material. The results also show the effect of HAZ on the shape of plastic zone ahead of crack tip and fracture parameters.

COMPUTATION MODEL

Chemical compositions and mechanical properties of a super steel SS400 are given in Table 1 and Table 2, respectively.

TABLE 1
CHEMICAL COMPOSITIONS OF THE SUPER STEEL SS400 (w.t.%)

C	Si	Mn	P	S	Al	Cu	Cr	Mo	Ni
0.171	0.09	0.36	0.013	0.013	0.025	0.01	0.02	0.01	0.03

TABLE 2
MECHANICAL PROPERTIES OF THE SUPER STEEL SS400

Material	Tension strength σ_b(MPa)	Yield strength σ_s(MPa)	Elongation δ_5(%)
SS400	480	365	31

The plate is welded by a pulse metal arc gas (PMAG) shielded welding process. The welding wire used is JS40Cu and the welding heat input is 3.0KJ/cm. The distribution of hardness of the practical welded joint is shown in Figure 1.

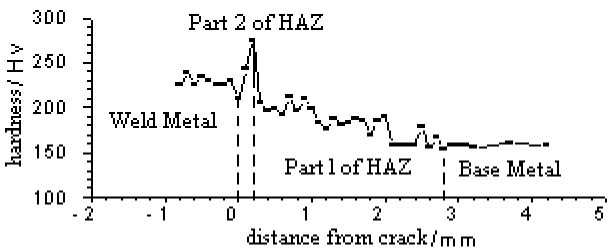


Figure 1: Hardness distribution of the practical welded joint

It can be seen from Figure 1 that the welded joint is composed of base metal, heat affected zone (HAZ) and weld metal. HAZ contain two parts approximately with different hardness, the softer part near base metal is labeled as Part 1 and the harder part near weld metal is labeled as Part 2.

The computation model is a thin plate and big size of wide plate specimen under tension, which is shown in Figure 2. Thickness of the plate is 2.8mm. Crack is located in the interface between Part 2 of HAZ and weld metal.

For the symmetry of specimen, only 1/4 of the whole specimen is computed. 20 nodes hexahedron element is used in the computation. Finite element mesh is shown in Figure 3. The mesh of weld metal and HAZ is dense. Crack tip use obtuse model with radius of 0.002mm. On the direction of thickness two layers of elements are meshed, and the elements of the layer near the center of plate is thinner. The mesh has a total of

14104 elements and 78625 nodes.

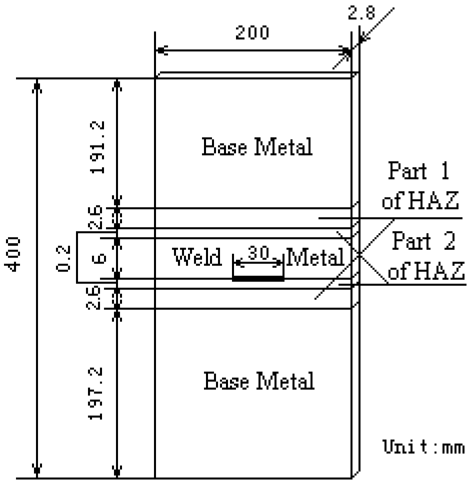
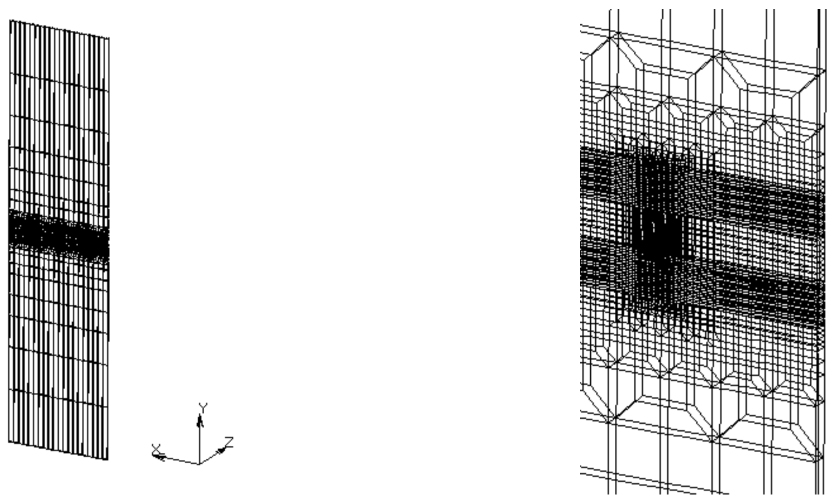


Figure 2: Sketch map of computation model



(a) Whole mesh (b) Local mesh

Figure 3: Mesh for finite element computation

Yield strength of the super steel SS400 base metal is 365Mpa based on the result of test, and the yield strength of other parts of welded joint is estimated according to the hardness distribution tested. For the simplification of computation, hardness distribution model showing in Figure 4 is used.

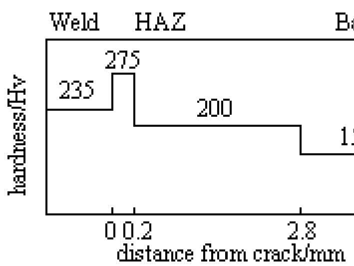


Figure 4: Simplified hardness distribution model of welded joint

In the computation, it is assumed that the whole model consists of four parts as base metal, Part 1 of HAZ, Part 2 of HAZ and weld metal. The uniaxial tensile stress-strain relation follows the pure power hardening law, which is given as,

$$\varepsilon / \varepsilon_y = \alpha \left(\sigma / \sigma_y \right)^n \tag{1}$$

Where ε, σ are the true strain and true stress, respectively, and ε_y, σ_y are the yield strain and yield stress, respectively. α is the hardening coefficient, and n is the power hardening exponent, which is assumed to follow the empirical equation[5],

$$n = 1/\left[k \ln\left(1390/\sigma_y\right)\right] \tag{2}$$

where k is the constant which is equal to 0.12. Table 3 shows σ_y and n value of each part of welded joint. It is assumed that elasticity module is the same for different part and is equal to 210,000MPa and Possion ratio is 0.3.

TABLE 3

VALUES OFσ_y AND n IN EACH PART OF WELDED JOINT FOR STEEL SS400

	Base Metal	Part 1of HAZ	Part 2 of HAZ	Weld Metal
σ_y (MPa)	365	487	669	572
n	6.23	7.95	11.4	9.39

For contrast, wide plate tension specimen of whole SS400 base metal with same size and same mesh is computed.

The present 3D FEM computations are performed using a software of MARC. Stress loading is used, and the maximum stress is 440MPa which is about 1.2σ_y whereσ_y is yield stress of SS400. J integral is calculated using DeLorenzi Virtual Crack Extension (VCE) method, and CTOD is measured using 45° angle method.

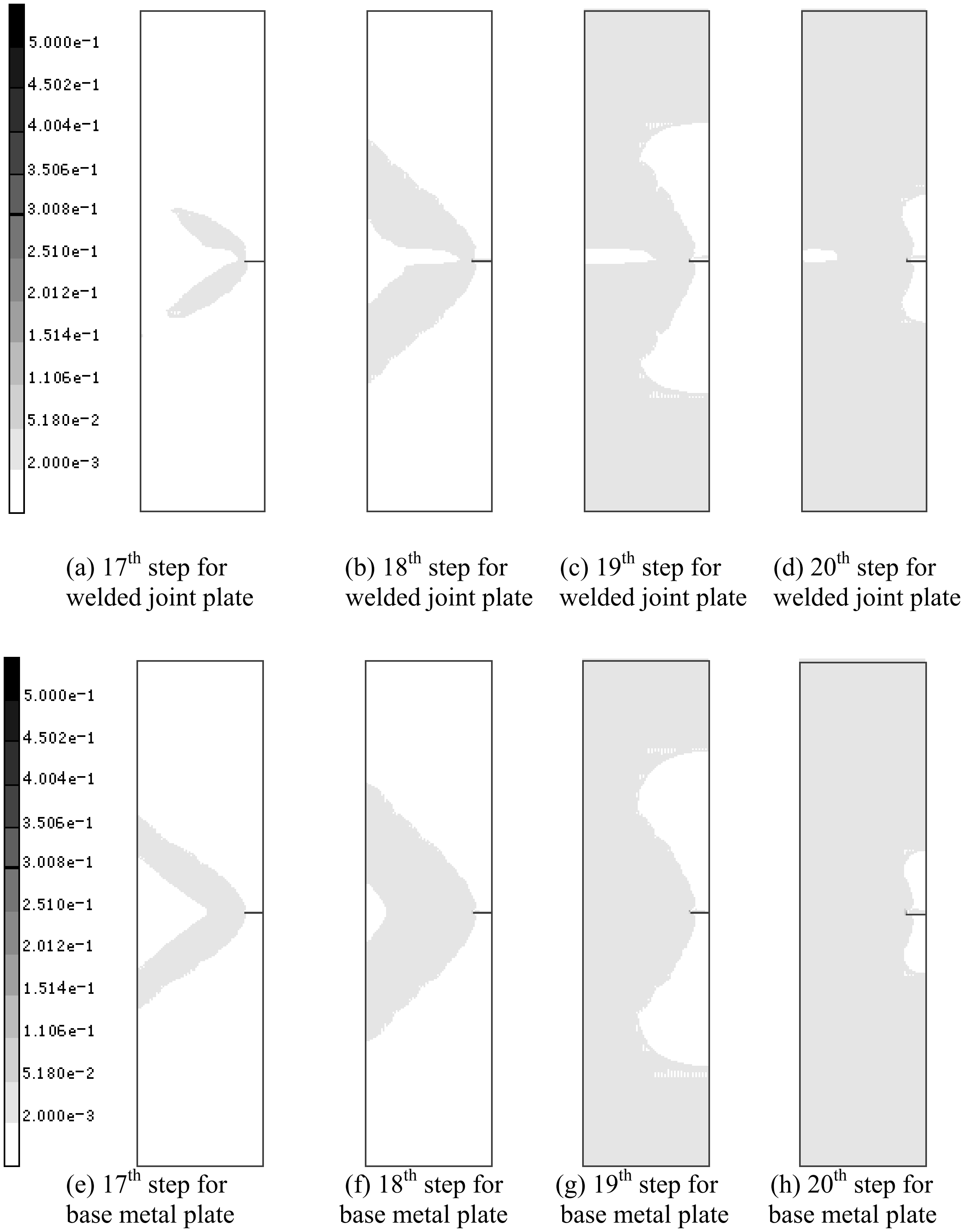
RESULTS AND DISCUSSIONS

Figure 5 shows yield zones of 17^{th} to 20^{th} computation steps of the wide plate tension model for welded joint and whole base metal. Yield zones are expressed by equivalent strain on the mid-section in thickness direction. Applied loads are 340MPa, 360MPa, 380MPa and 400MPa respectively for the relevant loading step.

It can be seen from Figure 5 that ligament yield takes place at the 18^{th} step and full yield takes place at the 19^{th} step for both welded joint and whole base metal. At the 17^{th} step, the yield zone of welded joint plate is smaller than that of whole base metal plate, because the yield strength of the base metal is lower than that of weld metal and HAZ. At the 19^{th} step, the full yield zone in the part of base metal of welded joint plate is bigger than that in whole base metal plate. The reason is that the harder weld metal and HAZ is difficult to deform under the protection of softer base metal, thus it is expected that the anti-fracture performance of welded joint plate is enhanced.

Figure 6 shows the local yield zone of weld metal and HAZ for welded joint plate, where for the whole base metal plate is at the 19^{th} loading step. The contour of yield zone breaks in the interface between parts of materials with different strength, and the shape of yield zone is asymmetry due to the strength difference. The influence of HAZ on the contour of yield zone can also be seen from Figure 6(a).

CTOD and J integral of welded joint plate and those of whole base metal plate in the same tension are compared in Figure 7. The values of both CTOD and J integral of welded joint plate are lower than those of whole base metal plate, and the difference between them becomes larger with increasing load, and J integral increases in approximately same trend as CTOD with increasing load. The reason is that yield strength of material near crack tip in welded plate is higher, thus crack tip is difficult to stretch. This indicates that driving force to fracture for welded joint plate with overmatched weld metal is smaller than that for whole base metal plate.



(a) 17th step for welded joint plate (b) 18th step for welded joint plate (c) 19th step for welded joint plate (d) 20th step for welded joint plate

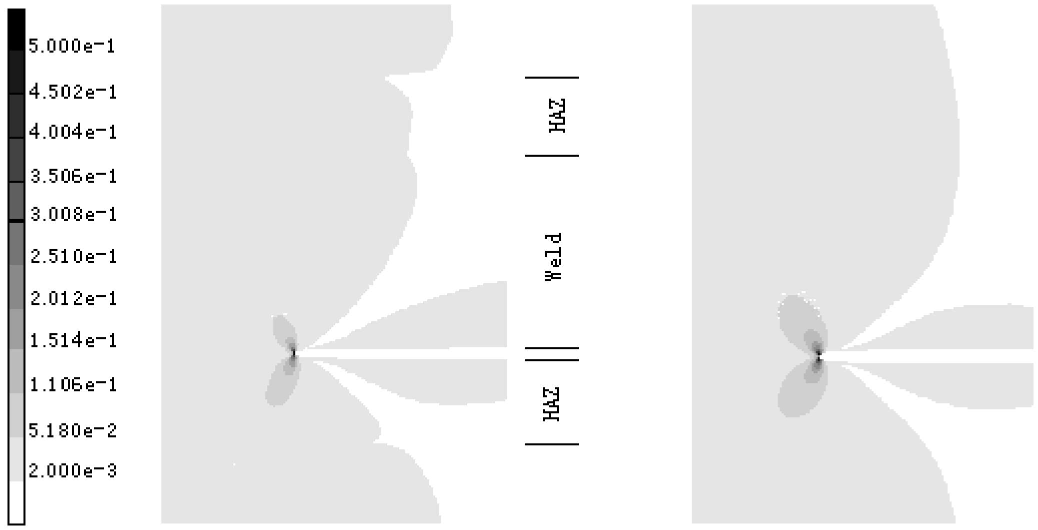
(e) 17th step for base metal plate (f) 18th step for base metal plate (g) 19th step for base metal plate (h) 20th step for base metal plate

Figure 5: Yield zone of 17th to 20th step of wide plate tension model for welded joint and whole base metal

CONCLUSIONS

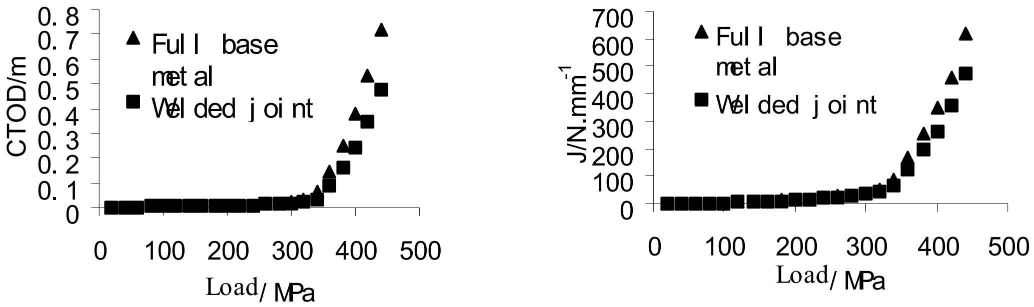
The present simulation of practical welded joint in tensile plate for super steel SS400 shows that existence of weld metal and HAZ in welded joint has important influence on the stress-strain field near crack tip, and yield zone is discontinuous when it passes through different parts of joint.

The computation results show that full yield is easier to take place in welded joint tensile plate than whole base metal plate, and driving force to fracture for welded joint plate is smaller than that for whole base metal plate.



(a) Welded joint plate (b) Whole base metal plate

Figure 6: Comparison of the local yield zone of weld metal and HAZ for welded joint plate and whole base metal plate



(a) Comparison of CTOD (b) Comparison of J integral

Figure 7: Comparison of CTOD and J integral for welded joint plate and whole base metal plate

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