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## Analysis of residual stress redistribution of weldment due to cutting

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**Key Words :** Residual stress ( ), Welding ( ), Cutting ( ), Finite element analysis ( )

### Abstract

In this paper, we conducted finite element analysis to investigate the residual stress redistributions of weldment due to cutting. To evaluate the effect of the residual stress on the fatigue behavior of weldment, test specimens are commonly cut from the weldment, but the distributions of the residual stress in the cut specimen should be different from those in the original weldment. Our work is to evaluate the difference between the residual stresses before and after weldment-cutting to understand the effect of cutting on the residual stress. Transient heat analysis, elastic-plastic mechanical analysis and element removal technique are used to simulate the welding and cutting procedures on the commercial finite element code ABAQUS.

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C:  $[J/(kg\ ^\circ C)]$

E: Young

K:  $[J/(s\ m\ ^\circ C)]$

q:  $[J/(m^2\ s)]$

$\epsilon^{pl}$  :

$\rho$ :  $[kg/m^3]$

$\sigma_y$ :  $[N/m^2]$

$\nu$ : Poisson

(1)

1.

ABAQUS

2.

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2.1

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1

0.1m × 0.37m

Fig

cutting line 1, ..., 1 1

. Fig 4

12

2600 °C

2.2

(cutting)

2

plane stress

2

3

가

(2, 3)

. Fig 5

Young's modulus

Poisson's ratio

. Fig 6

2

, Table 1

(4)

GMAW(Gas

Metal Arc Welding)

가

(SWS490A, carbon 0.2 max wt. %)

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$$q_0 = \frac{\eta_a VI}{\pi r_b^2} \frac{3}{2}$$

(Fig 1 )

가

$$q = q_0 e^{-3\left(\frac{r}{r_b}\right)^2}$$

. ABAQUS

$$q_0 \approx 260 \times 10^6 \text{ (J/m}^2\text{s)}$$

debond

, debond

(4).

Gaussian

3

0.5

가

bf

$$bf = 130 \times 10^6 \text{ (J/m}^3\text{s)}$$

0.01m

, Fig 1

1,

2

$$bf = 130 \times 10^8 \text{ (J/m}^3\text{s)}$$

...1 1

Fig 7 (a)-(f)

가

가

5

11

. Fig 8

Fig 7

가

2000 °C

가 6mm/s

( )

, 4

(σ<sub>11</sub>)

Fig 2  
specific heat  
C

, conductivity,  
, Fig 3 Fe-

(σ<sub>22</sub>)

727 °C  
(fcc iron)

(bcc iron)-  
specific heat 가

가

. 1500 °C  
specific heat

가가

가

11

conductivity

, Fig 9

가

**Table 1** Numerical parameter values

	$20^{\circ}C$
Filler metal	$2000^{\circ}C$
Solidus	$1465^{\circ}C$
Liquidus	$1544^{\circ}C$
	$247000 J/kg$
Arc $\eta_a$	0.4
$V$	105 V
$I$	150 ~ 190 A
Arc beam radius $r_b$	0.005m
	$10 J/(s m^2 ^{\circ}C)$

12

가

가

3.

2

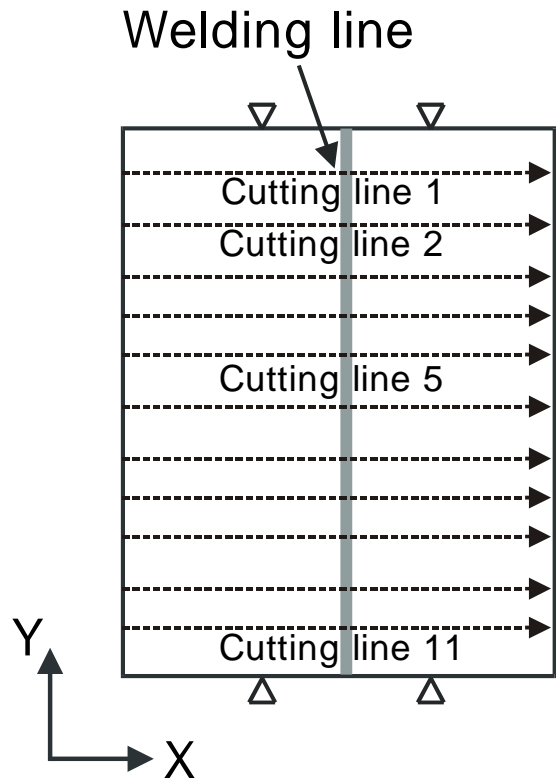
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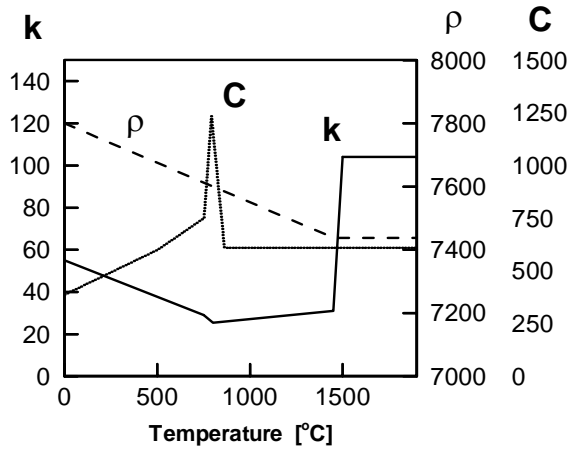
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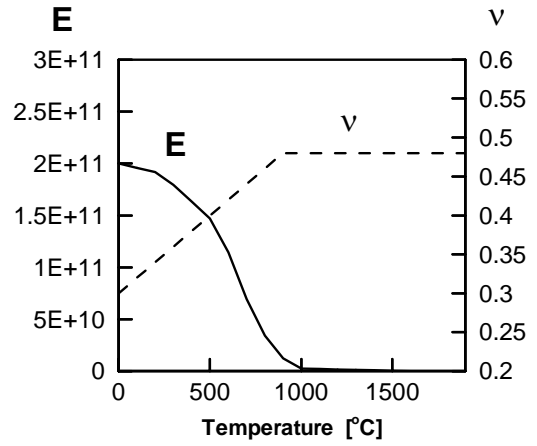
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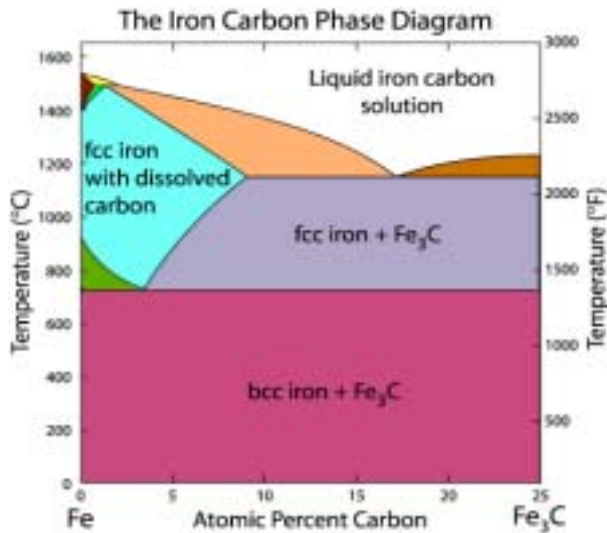
**Fig. 1** Welding proceeds downward along the welding line and the cutting goes from left to right. After cutting is completed, the plate is separated into 12 pieces.



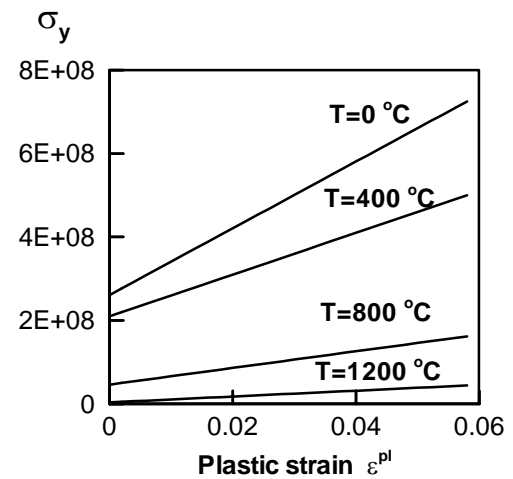
**Fig. 2** Variation of conductivity  $k$ , density  $\rho$  and specific heat  $C$  with temperature.



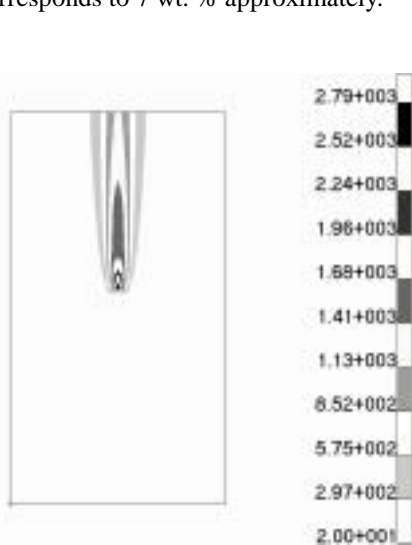
**Fig. 5** Variation of Young's modulus  $E$  and Poisson's ratio  $\nu$  with temperature.



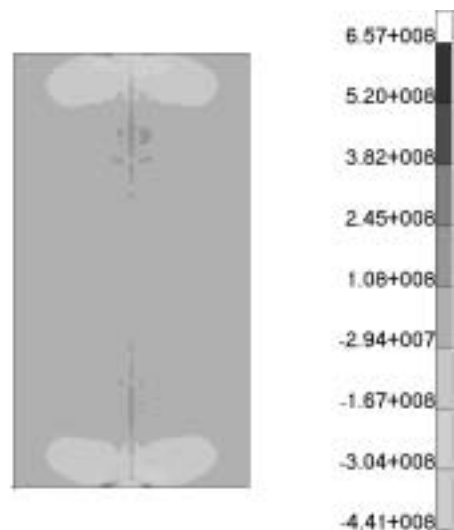
**Fig. 3** Fe-C phase diagram. 25 at. % of carbon corresponds to 7 wt. % approximately.



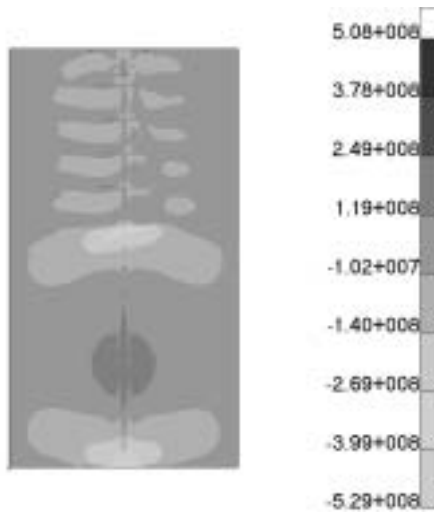
**Fig. 6** Yielding stress and plastic strain curves at several temperatures.



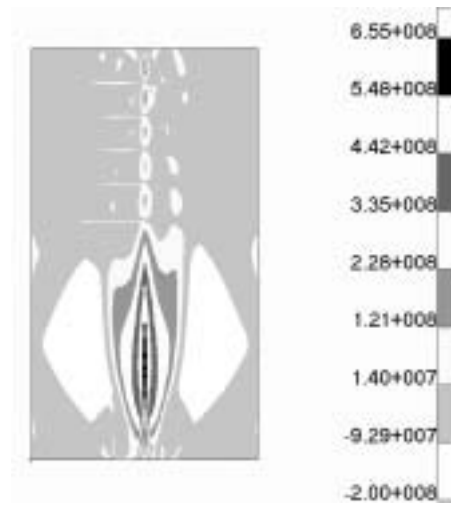
**Fig. 4** Temperature distribution at a time during the welding. The unit of temperature is  $^{\circ}C$ .



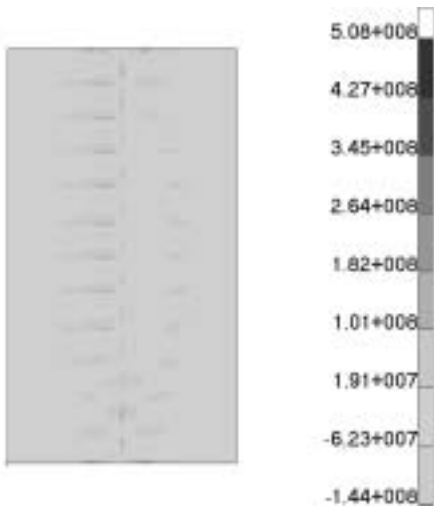
(a)  $\sigma_{11}$  distribution after welding is completed.



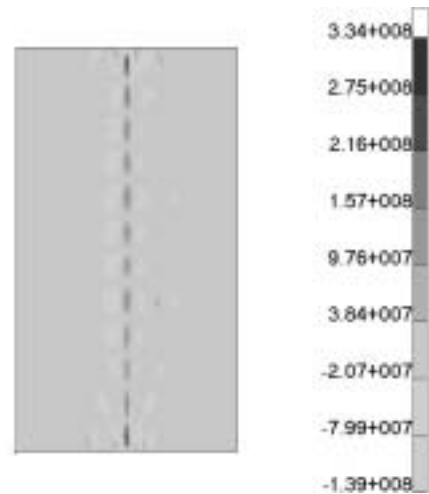
(b)  $\sigma_{11}$  distribution after cutting along the line 5.



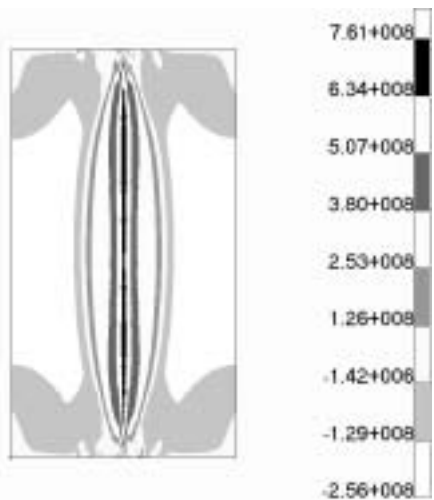
(e)  $\sigma_{22}$  distribution after cutting along the line 5.



(c)  $\sigma_{11}$  distribution after cutting along the line 11.

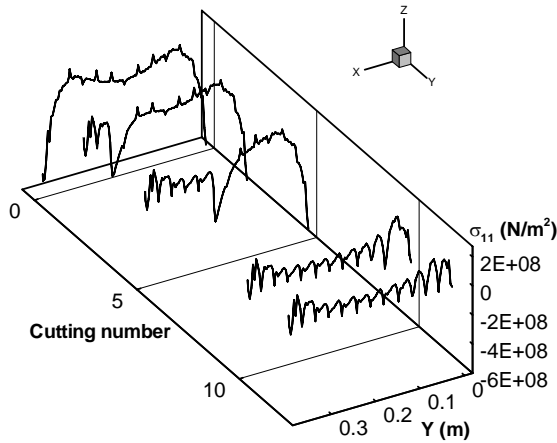


(f)  $\sigma_{22}$  distribution after cutting along the line 11.

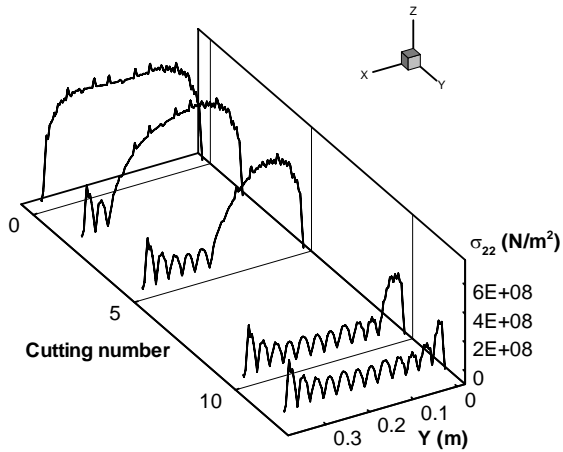


(d)  $\sigma_{22}$  distribution after welding is completed.

**Fig. 7** Residual stress distributions after welding and cutting. Distributions are plotted on the undeformed configuration.

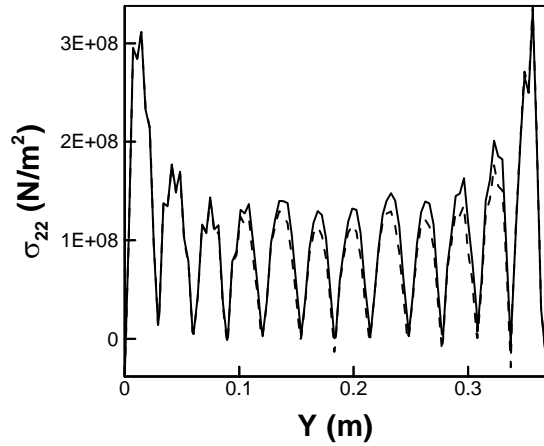
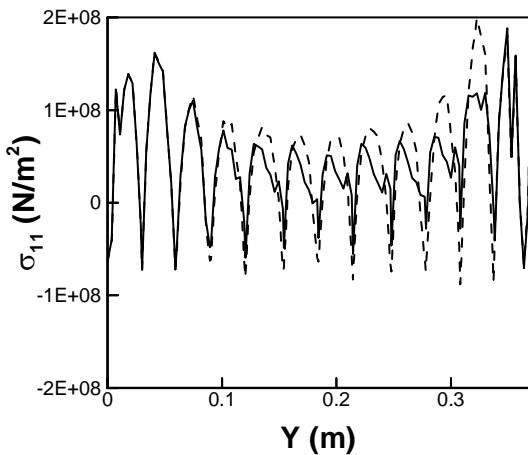


(a) Change of  $\sigma_{11}$  distribution during cutting procedure.



(b) Change of  $\sigma_{22}$  distribution during cutting procedure.

**Fig. 8** Change of residual stress distributions along the welding line at the center (Fig 1) during cutting procedure. Stresses are plotted when welding is completed (cutting number is 0) and after cutting along lines 2, 5, 10 and 11.



**Fig. 9** Solid lines: final residual stress distributions for the case of cutting along the lines 1, 2, ..., 11 one by one. Dashed lines: final residual stress distributions for the case of cutting along the cutting lines at the same time. Residual stress distributions are plotted along the welding line, and the horizontal axis corresponds to the y-coordinate in Fig 1.

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(2) , , , , 2003.

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(3) , , 2002.

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(4) , 1995.

GMAW