Solid-shell

Welding analysis with linear solid-shell element

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Key Words : Solid-shell elements( ), welding( ), shear locking( ), thickness locking( )

Abstract

In the FE analysis of sheet metal forming, efficient results can be obtained by using shell elements rather than using solid elements. However, shell elements have some limitations to describe three-dimensional material laws. In the recent years, solid-shell element, which has only translational degree of freedom like solid element, has been presented. The assumed nature strain (ANS) and enhanced assumed strain (EAS) methods can be used to remove several solid-shell locking problems. In this paper, ANS method was used for diminish transverse shear locking and EAS method for thickness locking. Using the element, the steel pipe making process from flat plate analyzed effectively, which is including bending and welding.

1.

solid shell . Shell degenerated shell[1] . shell . . , solid transition [2]. 3 solid translational d.o.f. solid-shell [3,4]. translational d.o.f. rotational d.o.f. shell

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. 3 . aspect ratio . - . (transformation plasticity) . shell . . shell . 3 shell 3 solid .

solid-shell

.

solid-shell

.

2. Kinematics of Solid-shell

Solid-shell shell (1,2) (4,5).

$$X(\bullet,\xi,\acute{}\,) | \frac{1}{2}\Psi(1\,2\,\acute{}\,)X_u(\bullet,\xi)\,2\,(1\,4\,\acute{}\,)X_l(\bullet,\xi)\beta \quad (1)$$

$$x(\bullet,\xi,\acute{}\,) | \frac{1}{2}\Psi(1\,2\,\acute{}\,)x_u(\bullet,\xi)\,2\,(1\,4\,\acute{}\,)x_l(\bullet,\xi)\beta \quad (2)$$

X_u, X_l

$\bullet\,4\,\xi$

. (1,2) solid-shell

(in-plane)

.

(1,2)

.

$$F | \frac{\in x}{\in X} \quad (3)$$

$$E | \frac{1}{2}/F^T F\,4\,I0 \quad (4)$$

3. Locking Effects

3.1 (Transverse shear locking)

shell solid solid-shell

.

(Assumed Natural Strain)

. 4

shell ANS [6]

. (5,6)

(4,5).

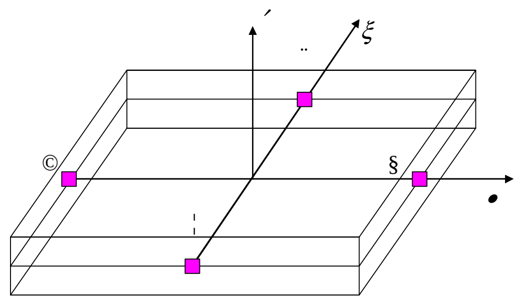

Fig. 1 ANS sampling points

$$E^{ANS}_{\xi\acute{}}(\bullet,\acute{}\,) | \frac{1}{2}(1\,4\,\bullet)E^{D}_{\xi\acute{}}\;2\;\frac{1}{2}(1\,2\,\bullet)E^{B}_{\xi\acute{}} \quad (5)$$

$$E^{ANS}_{\bullet\acute{}}(\xi,\acute{}\,) | \frac{1}{2}(1\,4\,\xi)E^{A}_{\xi\acute{}}\;2\;\frac{1}{2}(1\,2\,\xi)E^{C}_{\xi\acute{}} \quad (6)$$

3.2 (Thickness locking)

$E_{\bullet\bullet}$

. 0

Hook's law

$E_{\acute{}\acute{}}$

. solid-shell

$E_{\acute{}\acute{}}$

. $E_{\acute{}\acute{}}$

(thickness locking) .

$E_{\acute{}\acute{}}$

.

(7)

(7).

$$u | \frac{1}{2}\begin{pmatrix} 1\,2\,\acute{} & 0 & 0 & 1\,4\,\acute{} & 0 & 0 & 0 \\ 0 & 1\,2\,\acute{} & 0 & 0 & 1\,4\,\acute{} & 0 & 0 \\ 0 & 0 & 1\,2\,\acute{} & 0 & 0 & 1\,4\,\acute{} & 1\,4\,\acute{}^{\,2} \end{pmatrix}\begin{bmatrix} u_u \\ u_l \\ \eta \end{bmatrix} \quad (7)$$

Simo and Rifai[8] (Enhanced Assumed Strain)

. ,

.

Vu-Quoc[9] $E_{,,}$

(8)

.

(8) .

$$E^{EAS}_{,,} | E^{C}_{,,} 2 \frac{1}{\det J} ´[1 \bullet \xi] \zeta_1 \zeta_2 \zeta_3 \qquad (8)$$

4.

Leblond[10]

.

(hyperelastoplastic) [11].

-

.

$$\vartheta | [JU'43\zeta(\chi 4 \chi_0)U'']I 2 s$$
$$s | dev[\vartheta] \qquad (9)$$

Mises (flow rule)

.

$$\frac{1}{3} tr[\bar{b}^e]\nu | \sqrt{\frac{3}{2}}\bar{\kappa}^p \qquad (10)$$

Mises

.

5. Numerical examples

5.1 (Cantilever beam bending problem)

Figure 2 10

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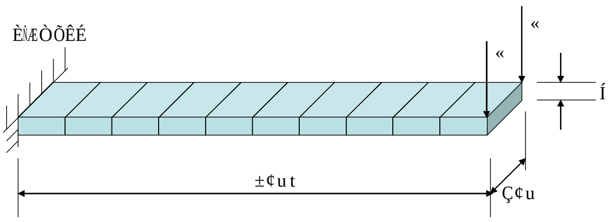

Fig. 2 10*1 Cantilever beam model

$$h | 1,0.1,0.01$$

. .

$$E | 1.0\Delta 10^7, \tau | 0.0 \qquad (11)$$

ANS 8 solid-shell 8 solid solid shear locking solid-shell (Fig. 3)

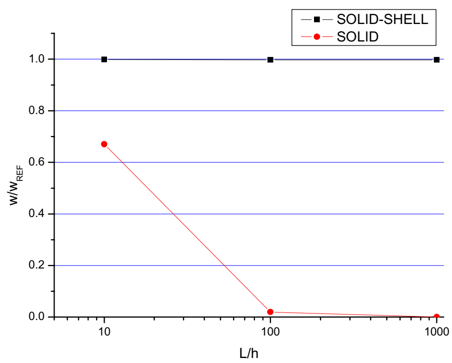

Fig. 3 ANS method in relieving shear locking

0.4 . ANS

80% .

EAS

Fig. 4

.

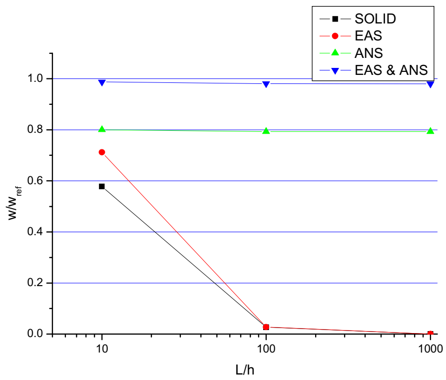

Fig. 4 ANS & EAS method in relieving thickness locking

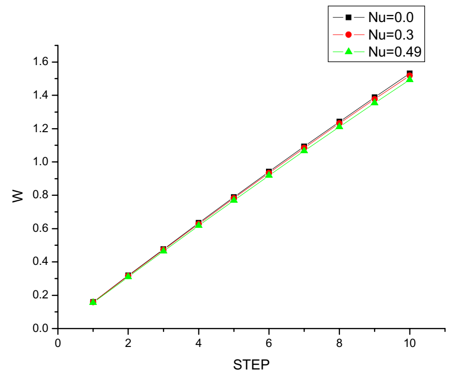

Fig. 6 Load deflection diagram with ANS & EAS method

(h | 0.1)

. 10

. EAS

stiff (Fig. 5).

Figure 6 EAS ((8)) locking

.

640 shell ABAQUS

(Fig. 7).

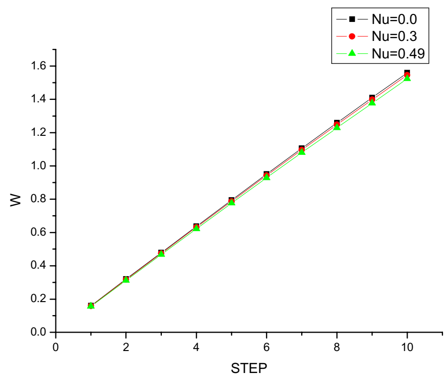

Fig. 7 Load deflection diagram with ABAQUS (S4R, 640 elements)

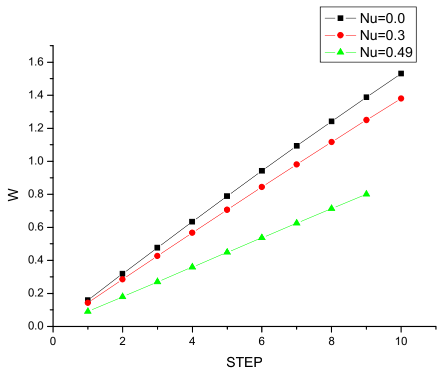

Fig. 5 Load deflection diagram with ANS method

5.2

. 107

100*10*1 .

.

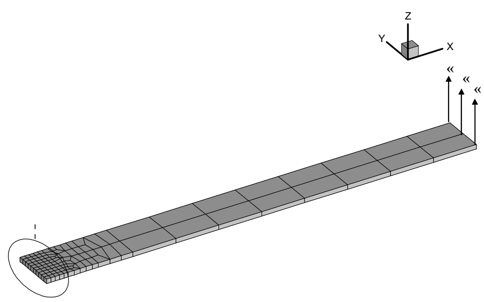

Fig. 8 Cantilever beam- bending and welding model

Figure 8 A POSCO Spiral seam

Z . .

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Figures 9,10 (time=1sec)

.

(coarse)

. solid

(aspect ratio)

solid-shell

.

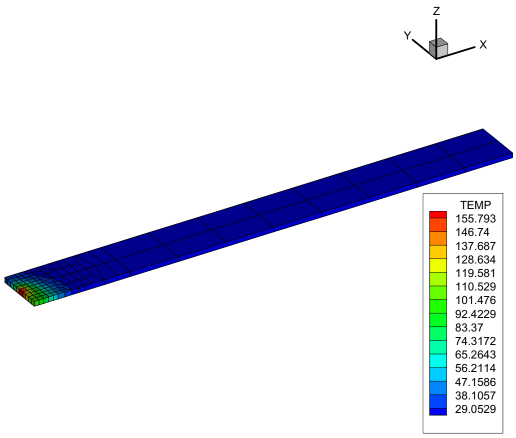

Fig. 9 Cantilever beam – Temperature plot at 1sec

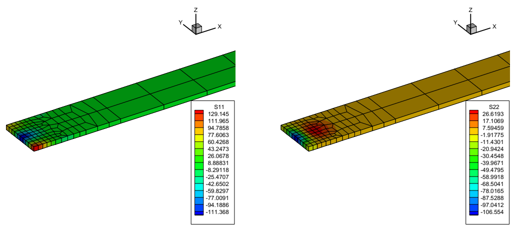

Fig. 10 Cantilever beam – stress plot at 1sec

6.

8

solid-shell (ANS)

(EAS)

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