Viscoelasticity

Because of the (explicit) solution method employed in the LS-DYNA, the dynamic effects (namely, ineria effects) cannot be removed from the results. Therefore, the extremely high rate of deformation causes the stress oscillation (implying inaccurate evaluation of stress).

Given this fact, for the example problems of stress relaxation, we examined only the results for the range of long relaxation time by setting the loading period at 1x10^(-3) sec. and the frequency of the harmonic vibrator at 1000 Hz.

To examine the material model in the LS-DYNA, the result obtained by the implicit method is shown in the next page (1hs50 only).
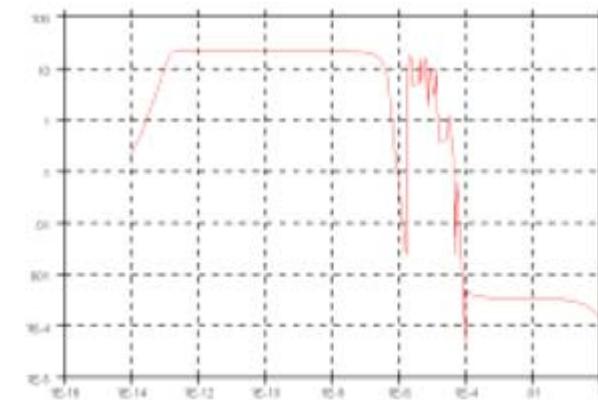
Appearance of drastic stress oscillation
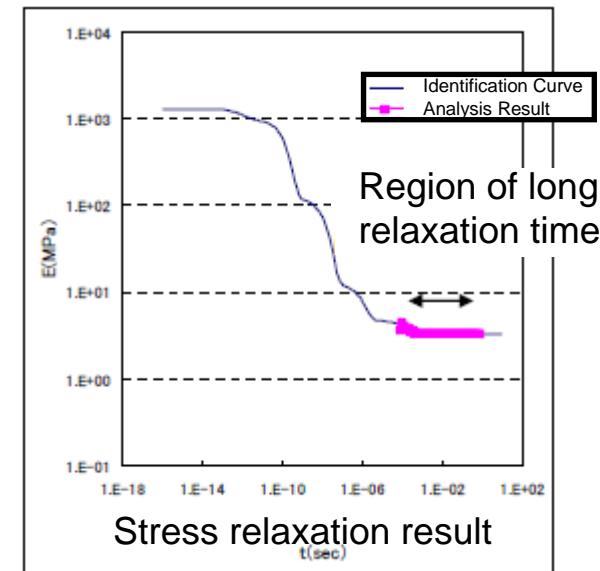
Region of long relaxation time

Stress relaxation result

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(stress_1hs50_imp.key)

LS-DYNA

```
*control_implicit_general
     1      1e-20
*control_implicit_auto
     1      0      0      0      -999
*DEFINE_CURVE
   999      0      1.0    1.0    0.0    0.0    0
          0.0            1.0e-20
     1.0000000E-18       1.0e-20
     1.0000000E-17       1.0e-19
     1.0000000E-16       1.0e-18
     1.0000000E-15       1.0e-17
     1.0000000E-14       1.0e-16
     1.0000000E-13       1.0e-15
     1.0000000E-12       1.0e-14
     1.0000000E-11       1.0e-13
     1.0000000E-10       1.0e-12
     1.0000000E-09       1.0e-11
     1.0000000E-08       1.0e-10
     1.0000000E-07       1.0e-09
     1.0000000E-06       1.0e-08
     1.0000000E-05       1.0e-07
     1.0000000E-04       1.0e-06
     1.0000000E-03       1.0e-05
     1.0000000E-02       1.0e-04
     1.0000000E-01       1.0e-03
     1.0000000E-00       1.0e-02
     1.0000000E+01       1.0e-01
```
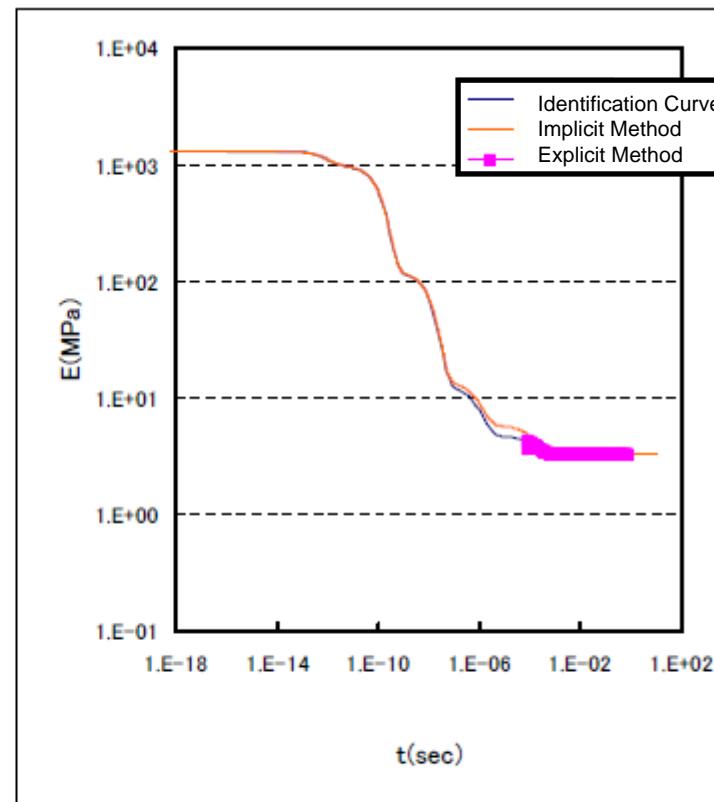

Stress-relaxation curve

LS-DYNA

Prony series

$$G(t) = \sum_{m=1}^{N} G_m e^{-\beta_m t}$$

Bulk Mdulus	
3.215E+04	

Gi(Mpa)	β i(1/sec)
2.739E+01	6.283E+14
1.682E+01	6.283E+10
1.894E+01	3.142E+08
8.299E−01	1.571E+05
2.171E−01	1.571E+02
1.430E−01	0.000E+00

Actual measurement along with fitted curve

Stress-relaxation curve with identified parameters

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LS-DYNA

1×10^{-4} mm
($\varepsilon = 0.1\%$)
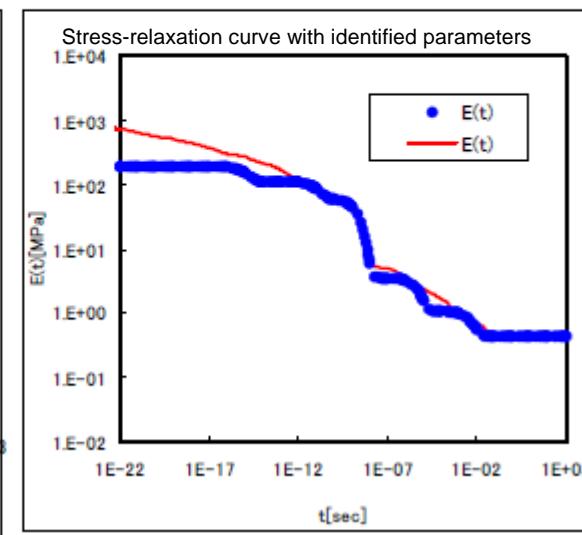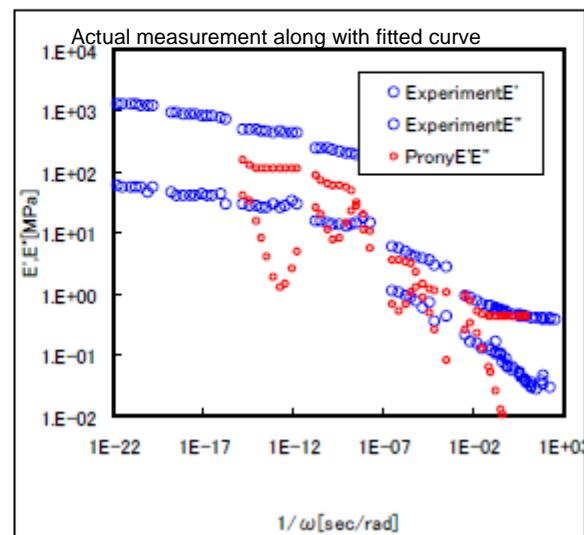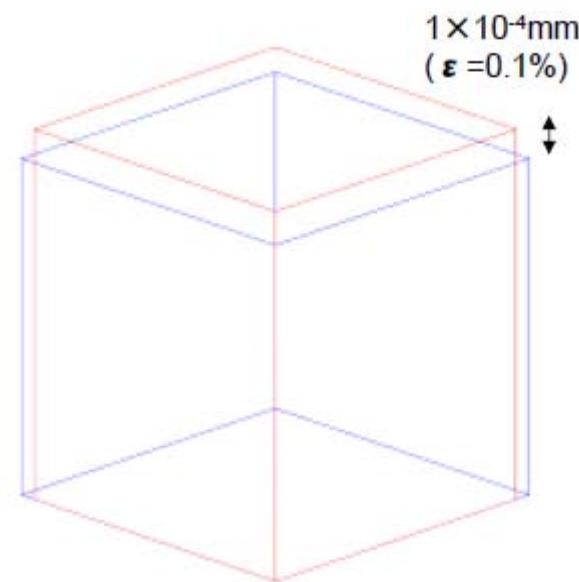
Analysis model

Stress-relaxation curve (graph):
- Y-axis: E(MPa), ranging from 1.E−01 to 1.E+04
- X-axis: t(sec), ranging from 1.E−18 to 1.E+02
- Identification curve
- Analysis Result

Stress-relaxation curve

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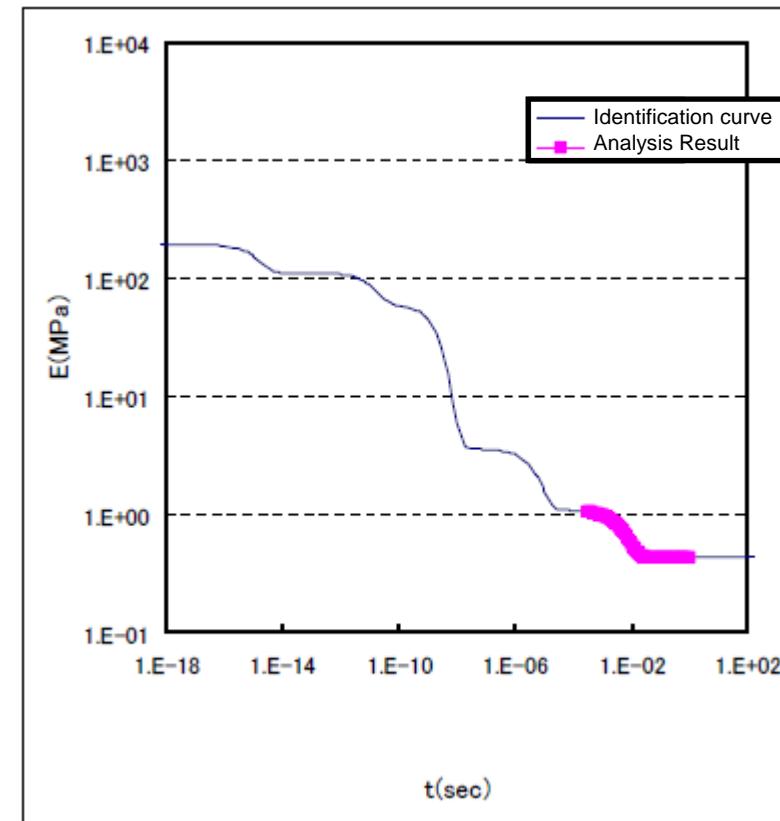
LS-DYNA

Amplitude5.0e-3mm
(ε=0.5%)

Analysis model
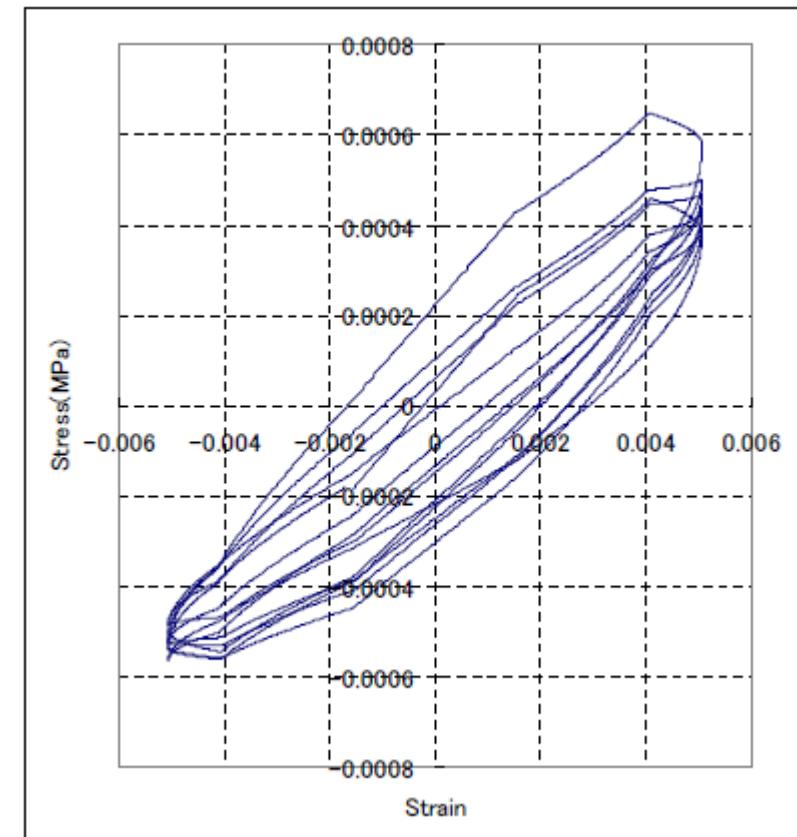
1000Hz hysteresis curve
SEAC1000 filtered