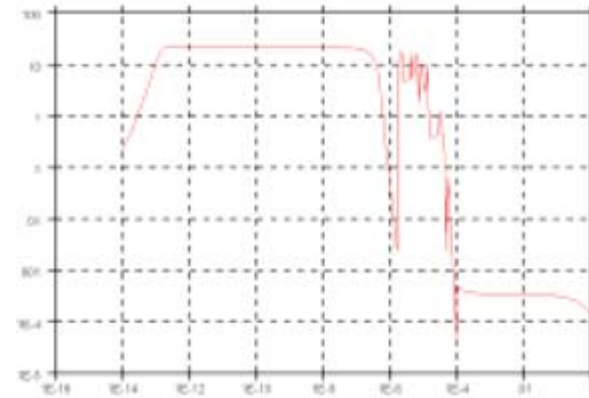


Viscoelasticity

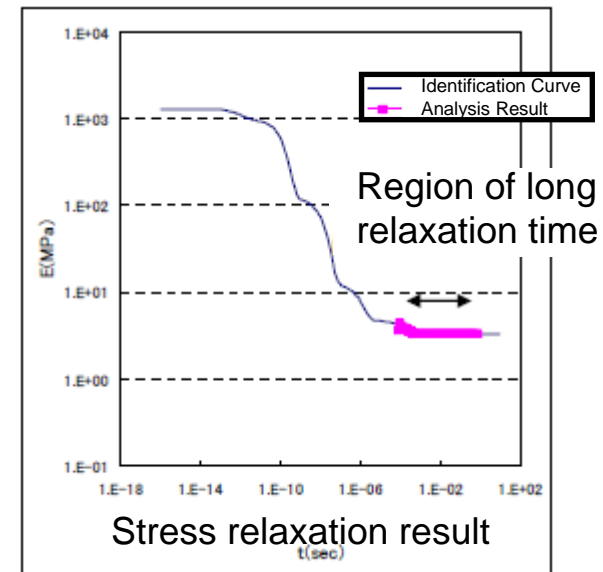
Because of the (explicit) solution method employed in the LS-DYNA, the dynamic effects (namely, inertia effects) cannot be removed from the results. Therefore, the extremely high rate of deformation causes the stress oscillation (implying inaccurate evaluation of stress).

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 1×10^{-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



Stress relaxation result

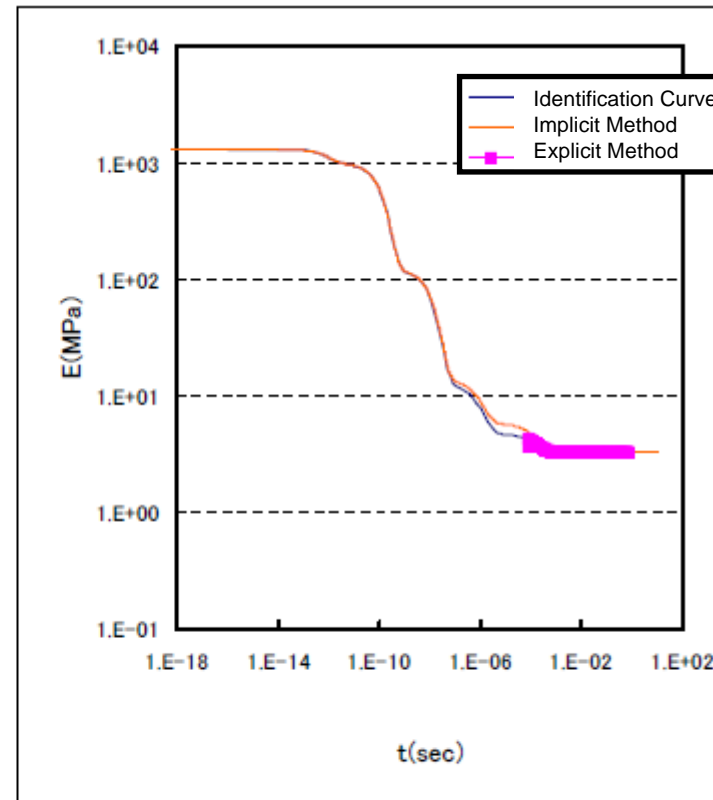
Reference: Computation by the implicit method

Hardness (50), Damping (Small) Stress-Relaxation Analysis

(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

Hardness (50), Damping (Large) Identification of material property

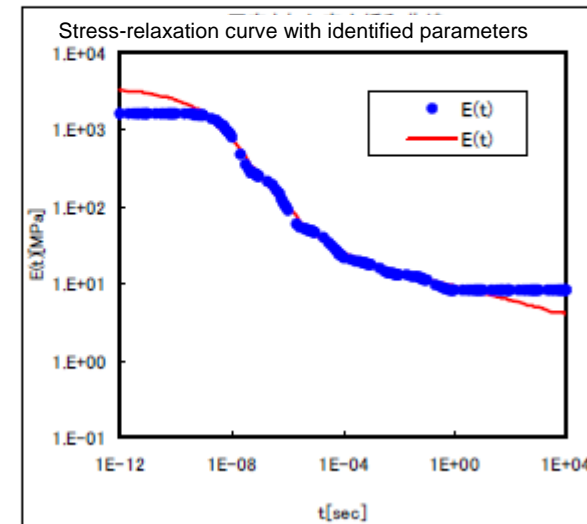
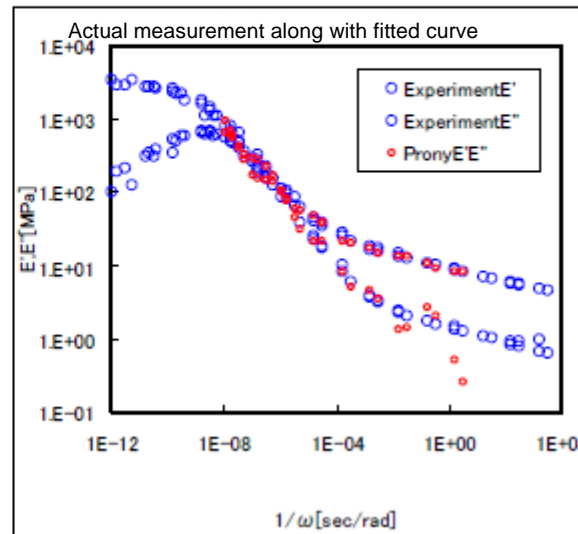
LS-DYNA

Prony series

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

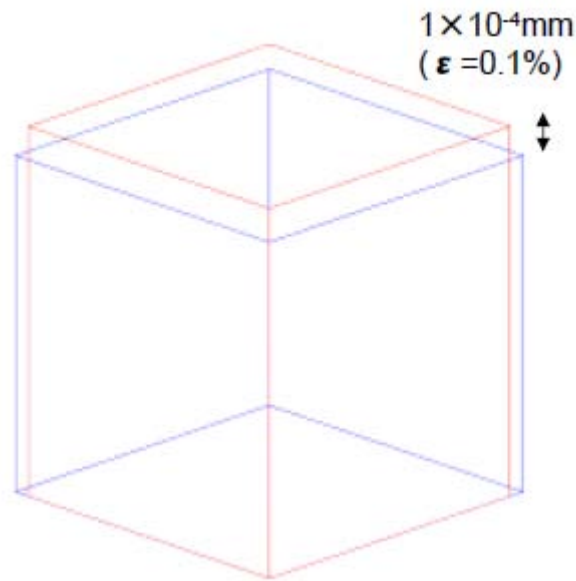
Bulk Mdulus	
2.709E+05	

Gi(Mpa)	$\beta_i(1/sec)$
4.460E+02	9.425E+07
7.779E+01	1.885E+06
1.135E+01	3.142E+04
2.538E+00	6.283E+02
1.737E+00	6.283E+00
2.758E+00	0.000E+00

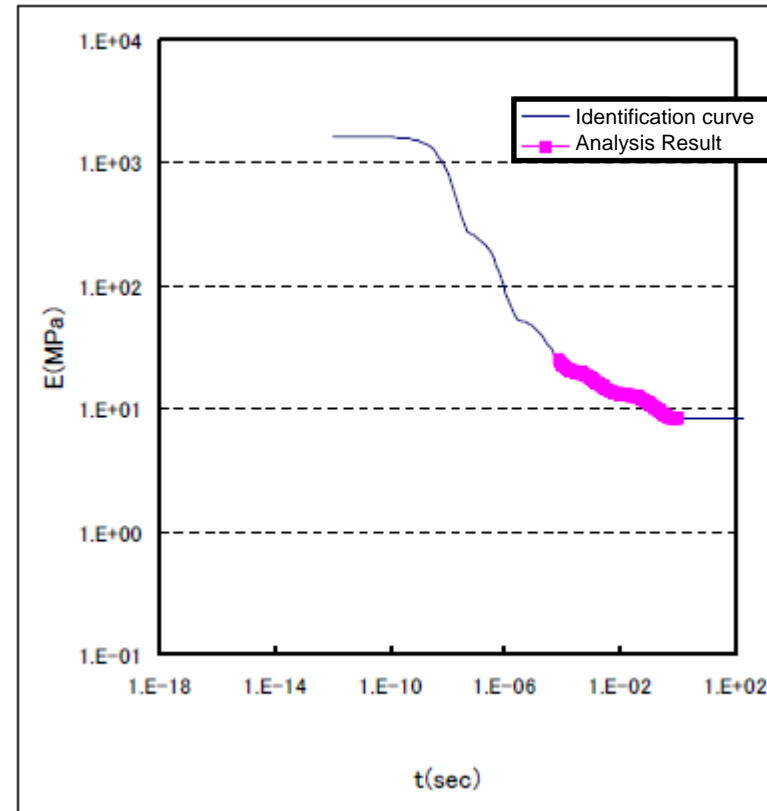


Hardness (50), Damping (Large) Stress-relaxation analysis (stress_2hs50.key)

LS-DYNA



Analysis model

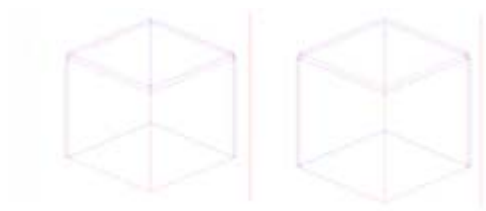


Stress-relaxation curve

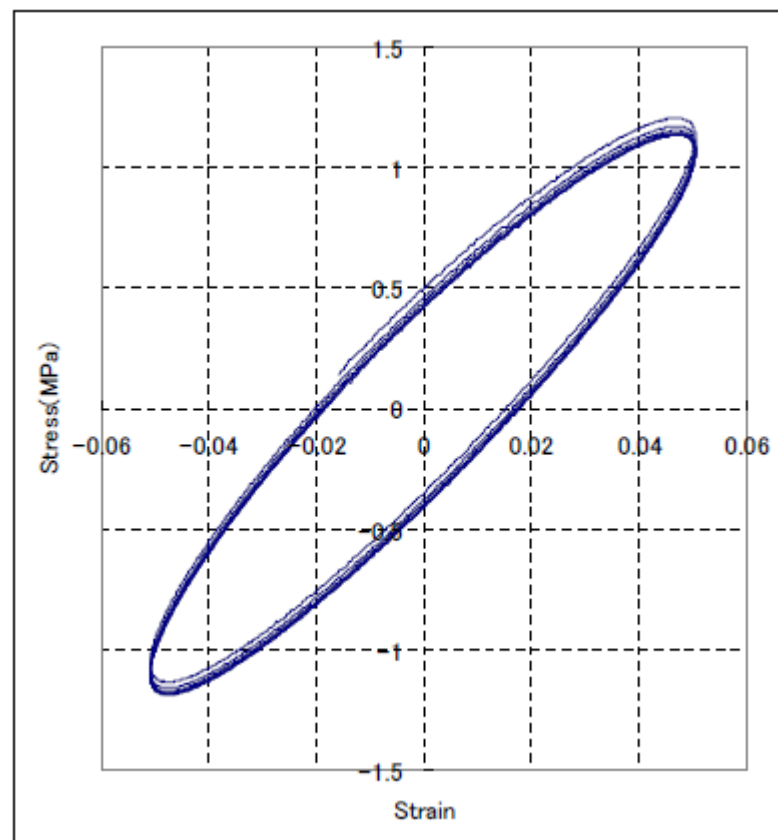
Hardness (50), Damping (Small) Harmonic vibration analysis (osc_2hs50.key)

LS-DYNA

Amplitude 5.0e-3mm
($\epsilon=0.5\%$)



Analysis model



1000Hz hysteresis curve