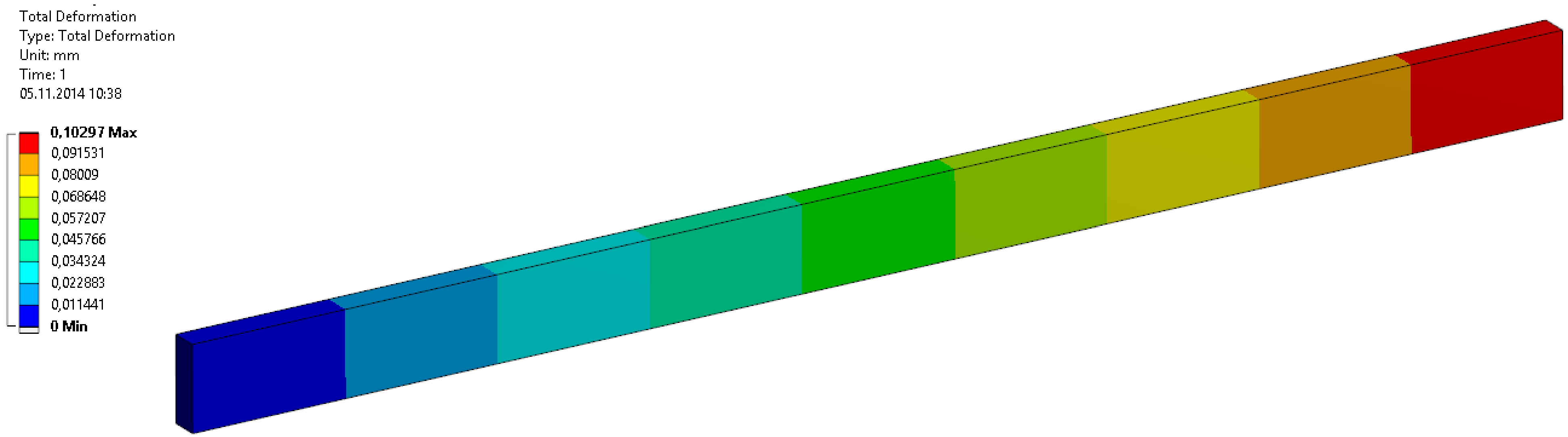
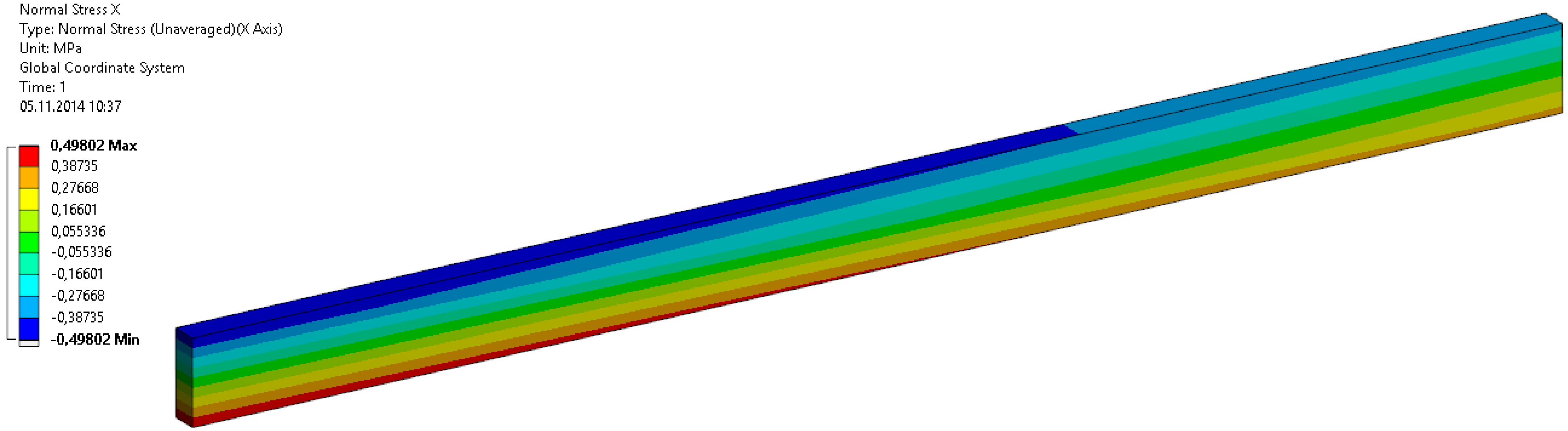
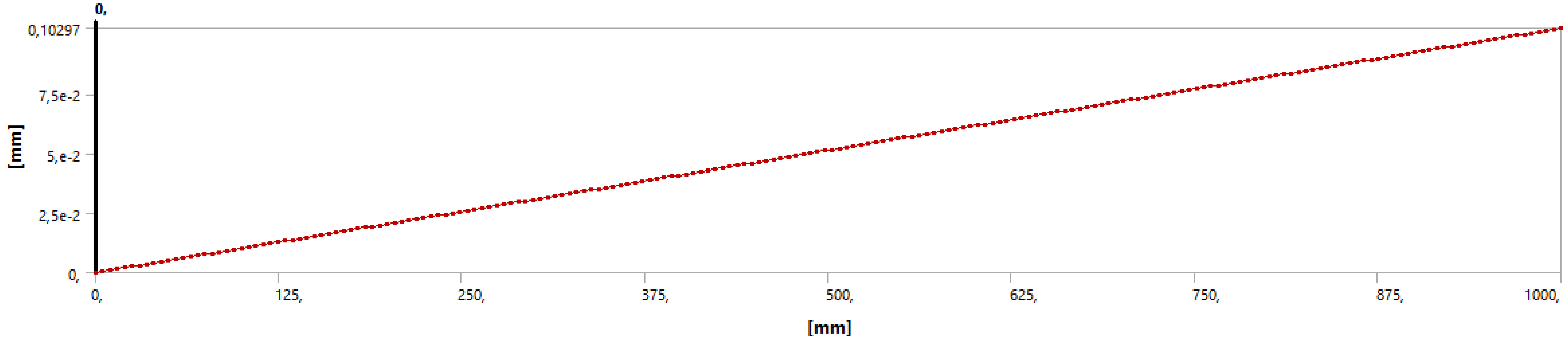
Single, Linear Hexahedron



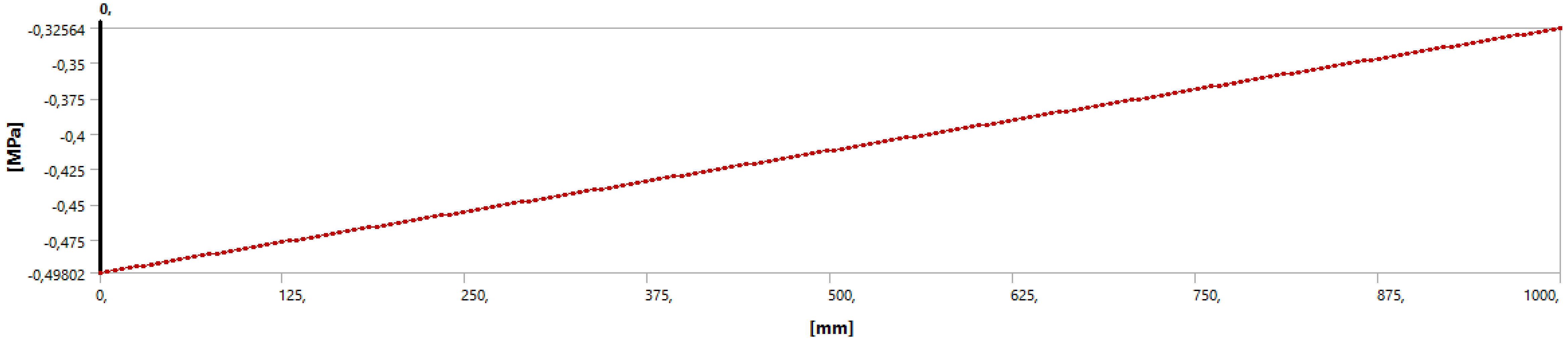


Single, Linear Hexahedron

Total deformation

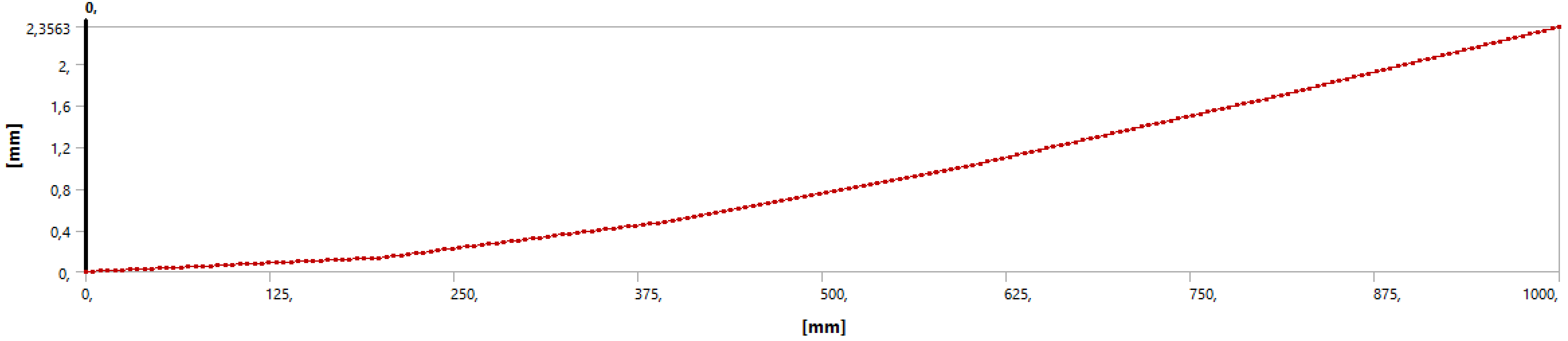


Normal stress, *x*

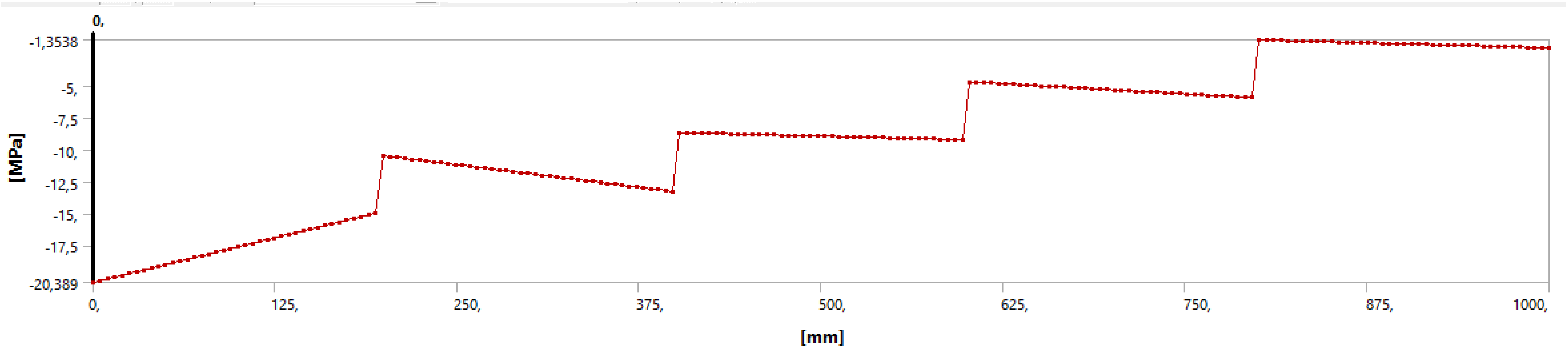


Five linear hexahedra

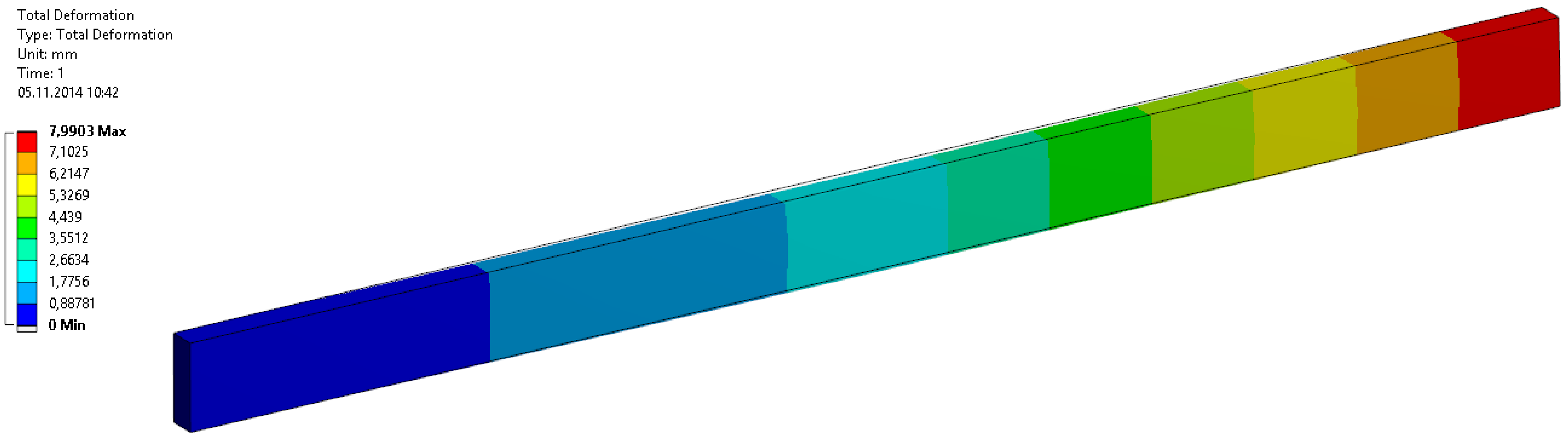
Total deformation

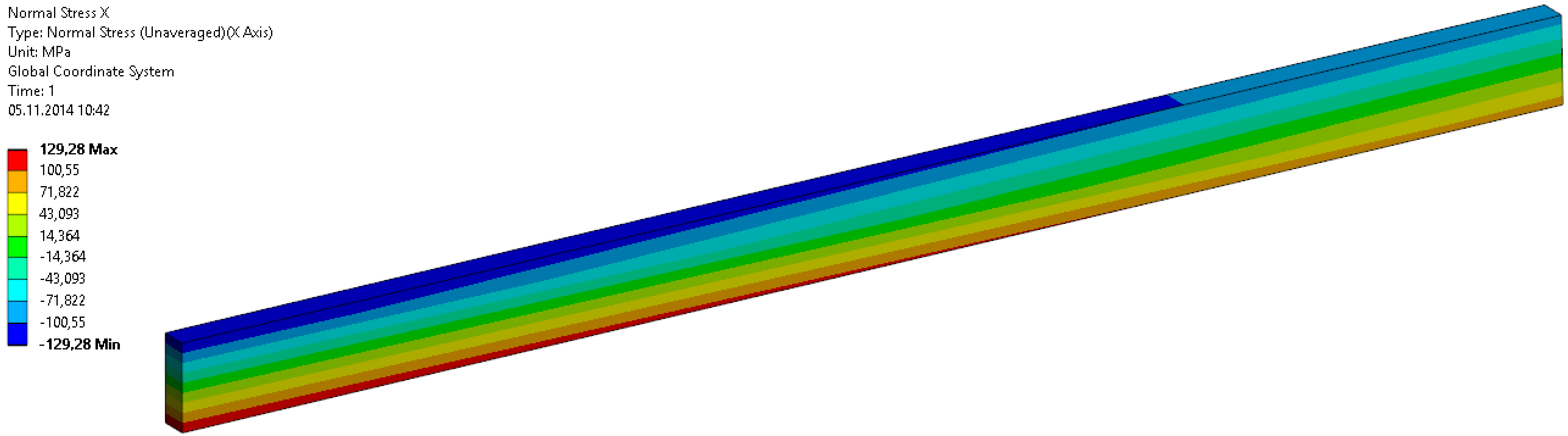


Normal stress, *x*



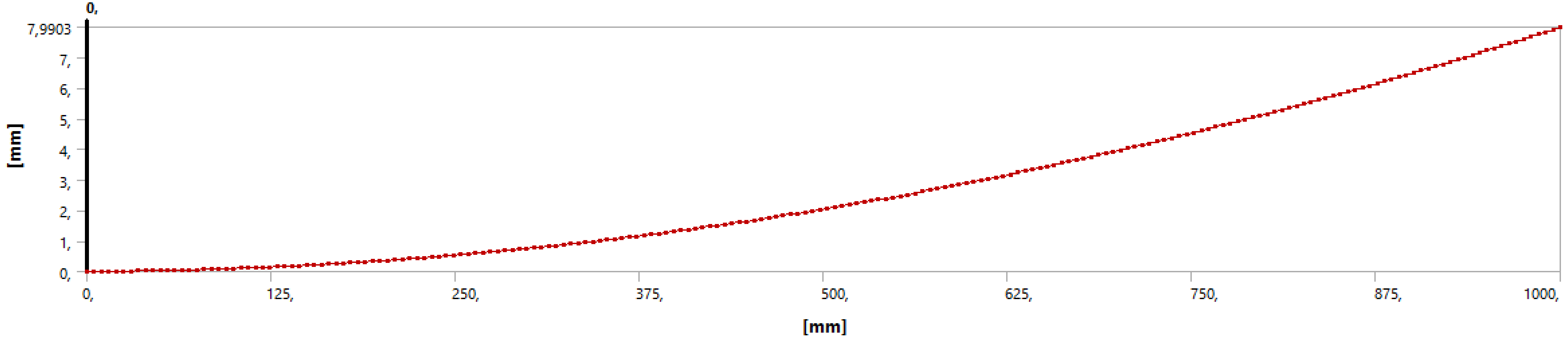
Single, Quadratic Hexahedron



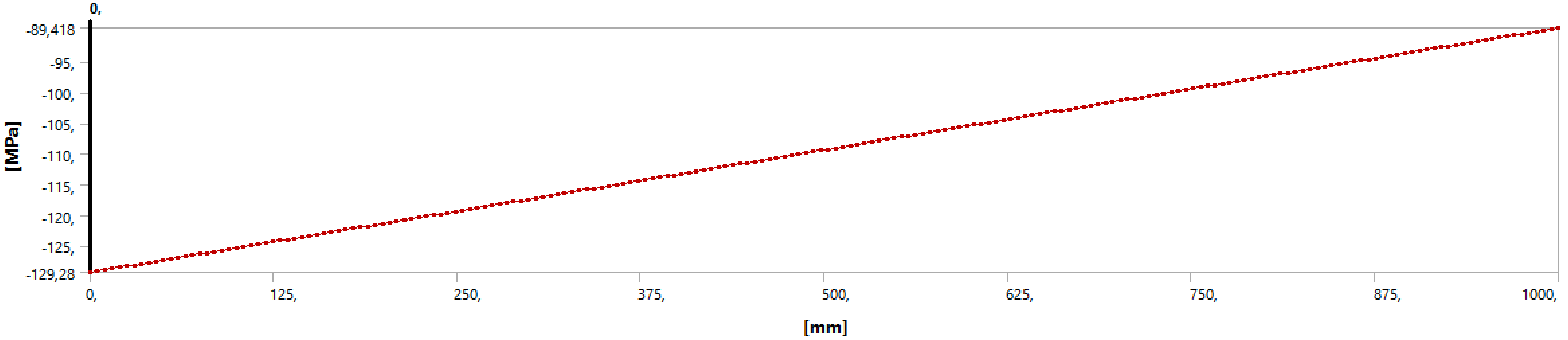


Single, Quadratic Hexahedron

Total deformation

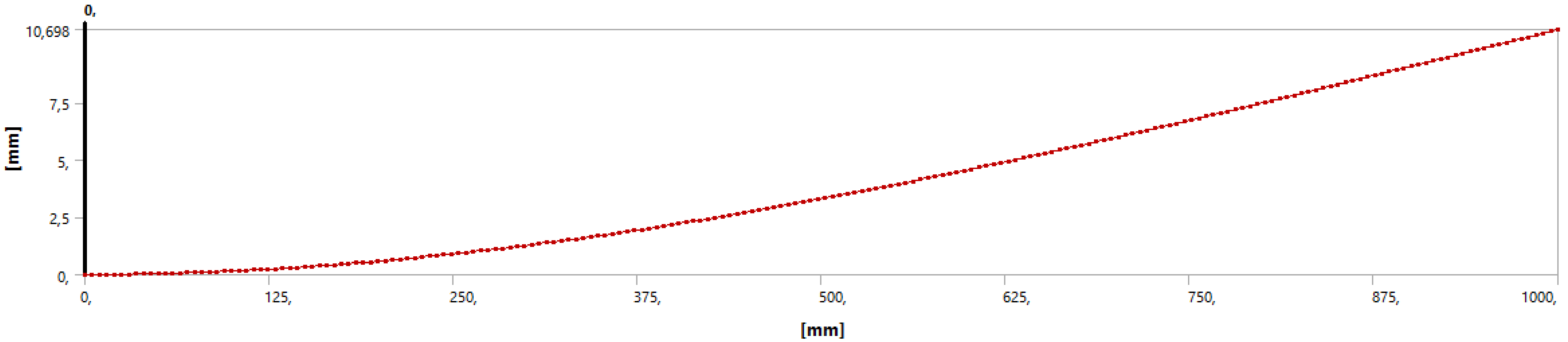


Normal stress, *x*

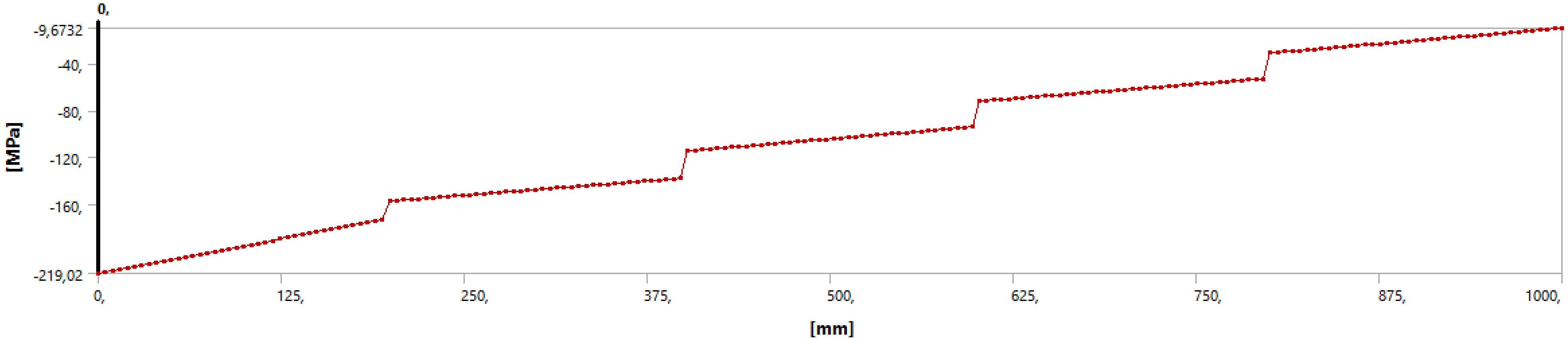


Five quadratic hexahedra

Total deformation

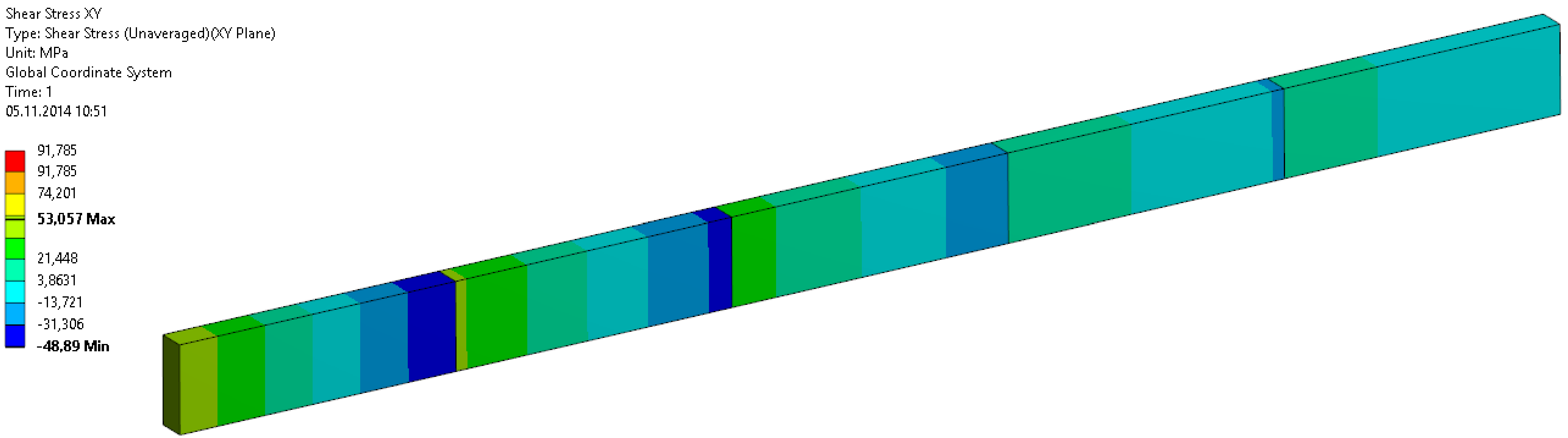


Normal stress, *x*

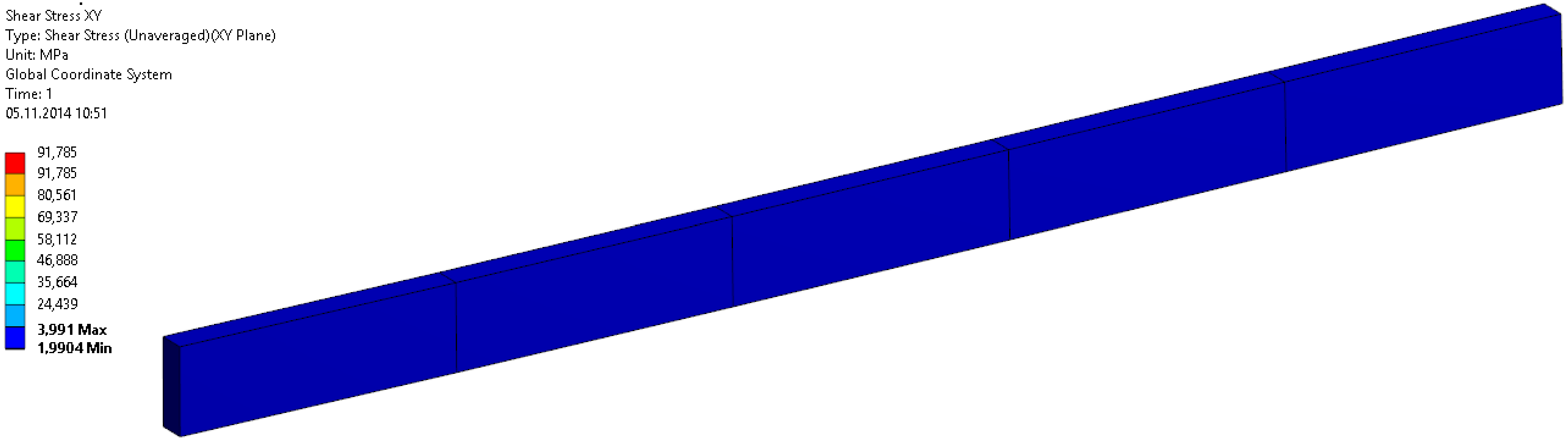


Five Linear vs. Quadratic Hexahedra

Linear



Quadratic



Shear Locking

Figure 4–4 Deformation of material subjected to bending moment *M*.

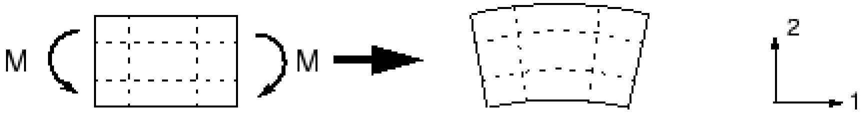


Figure 4–5 Deformation of a fully integrated, linear element subjected to bending moment *M*.

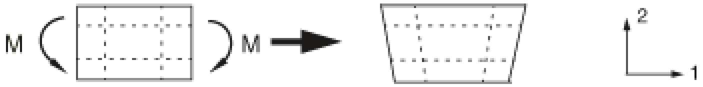


Figure 4–6 Deformation of a fully integrated, quadratic element subjected to bending moment *M*.

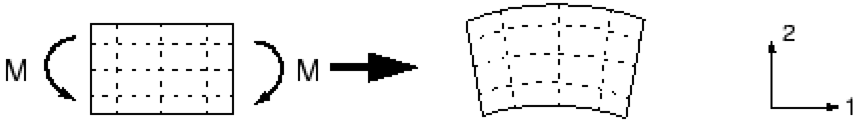


Figure 4–8 Deformation of a linear element with reduced integration subjected to bending moment *M*.

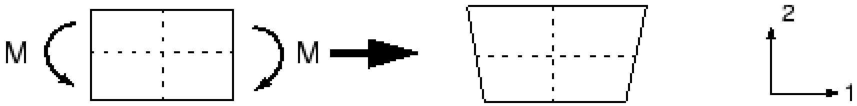


Figure 4–2 Integration points in fully integrated, two-dimensional, quadrilateral elements.

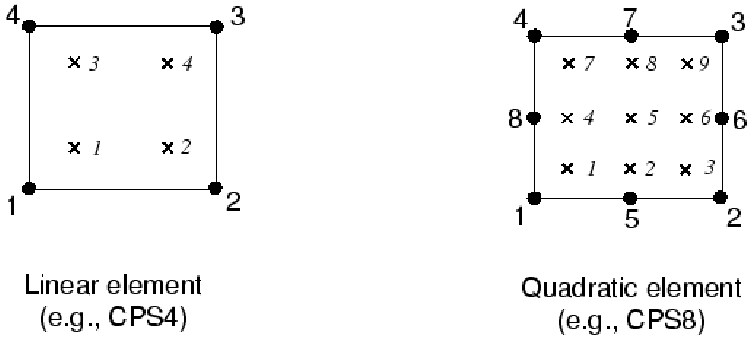
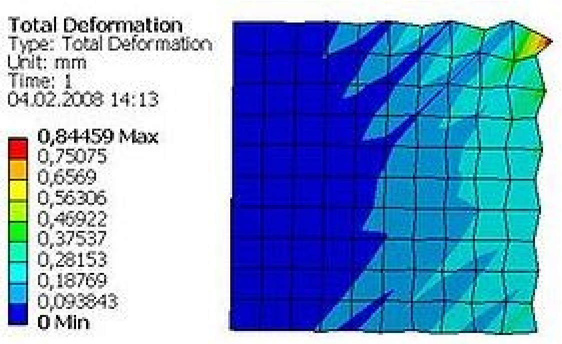


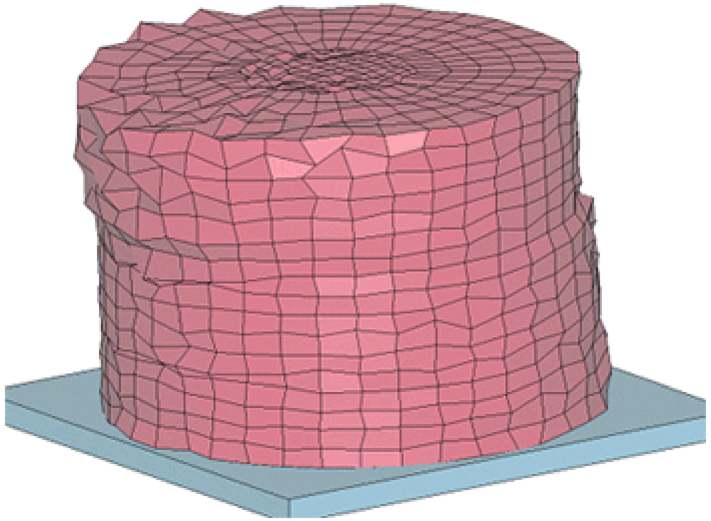
Figure 4–7 Integration points in two-dimensional elements with reduced integration.

Abaqus manual, chapter 4

Hourglassing



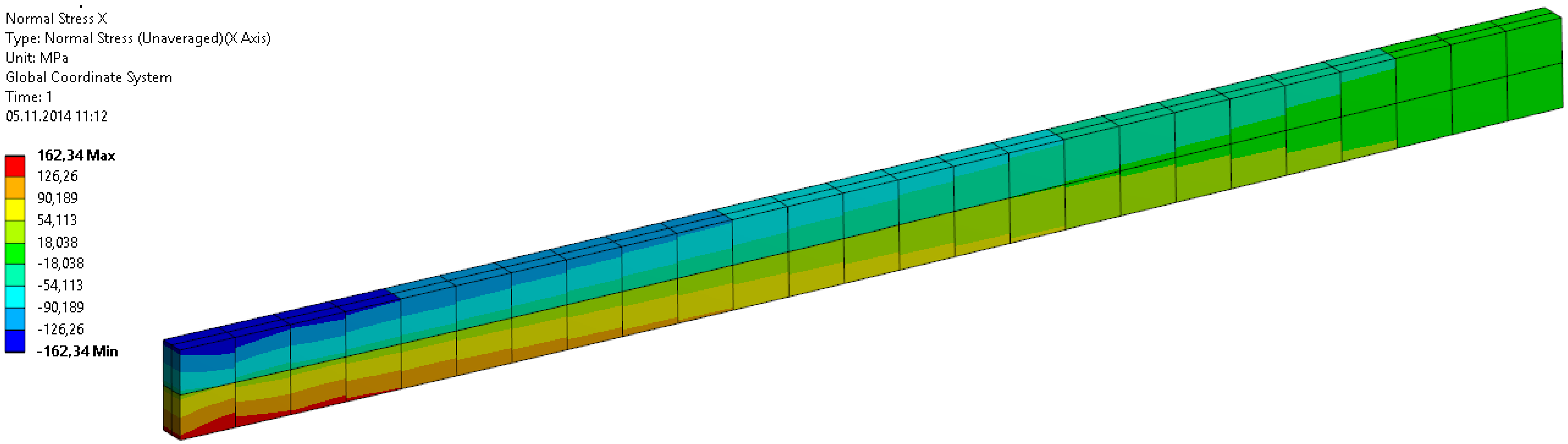
CADFEM Wiki



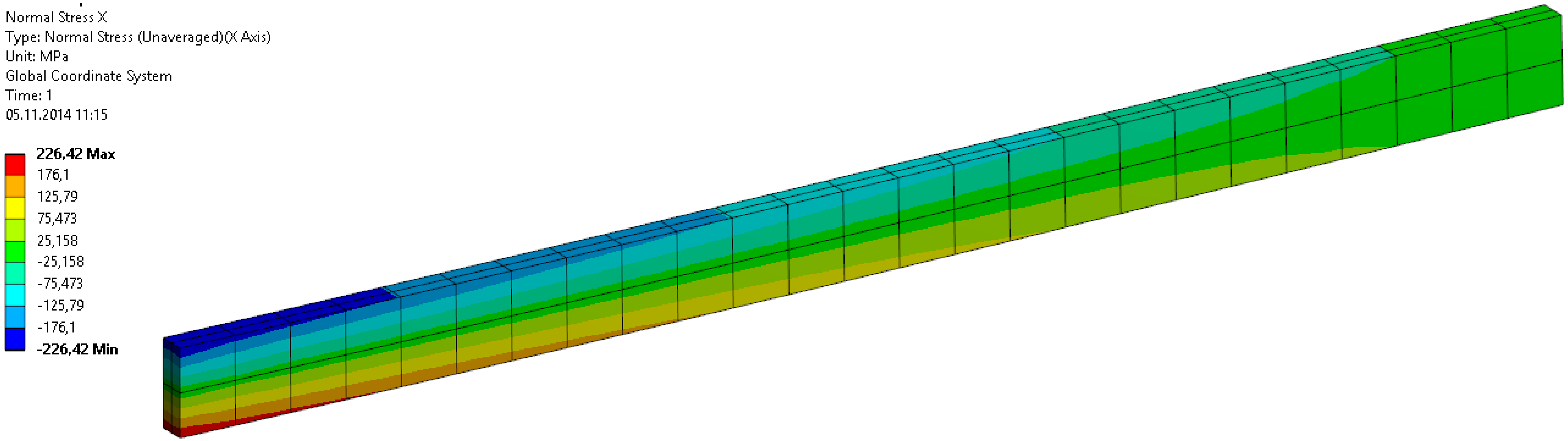
U.S. Federal Highway Administration

25x2x2 Hexahedra

Linear

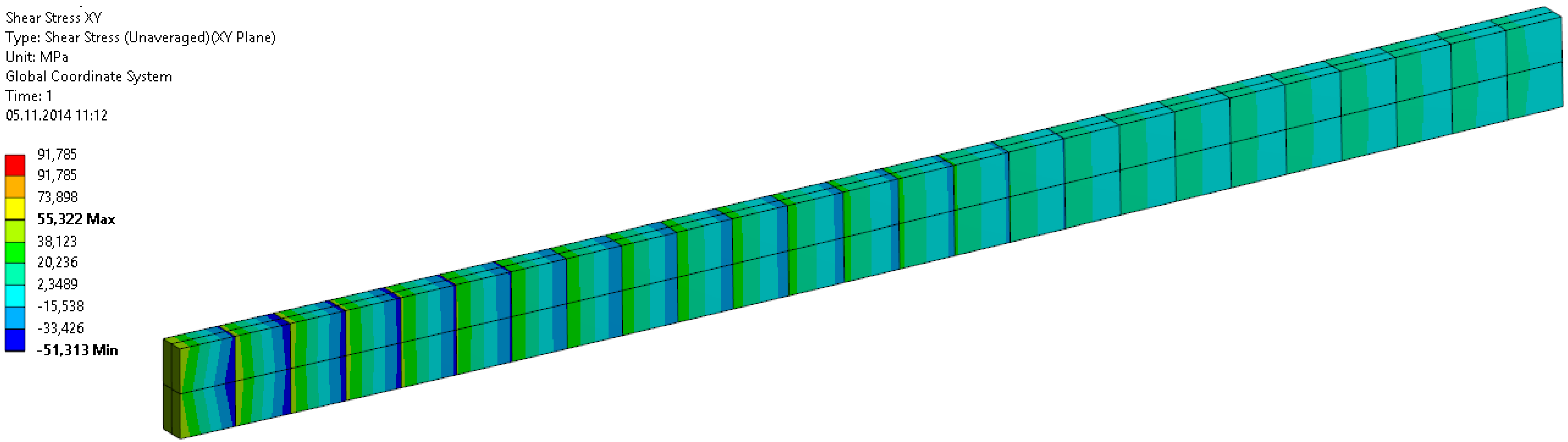


Quadratic

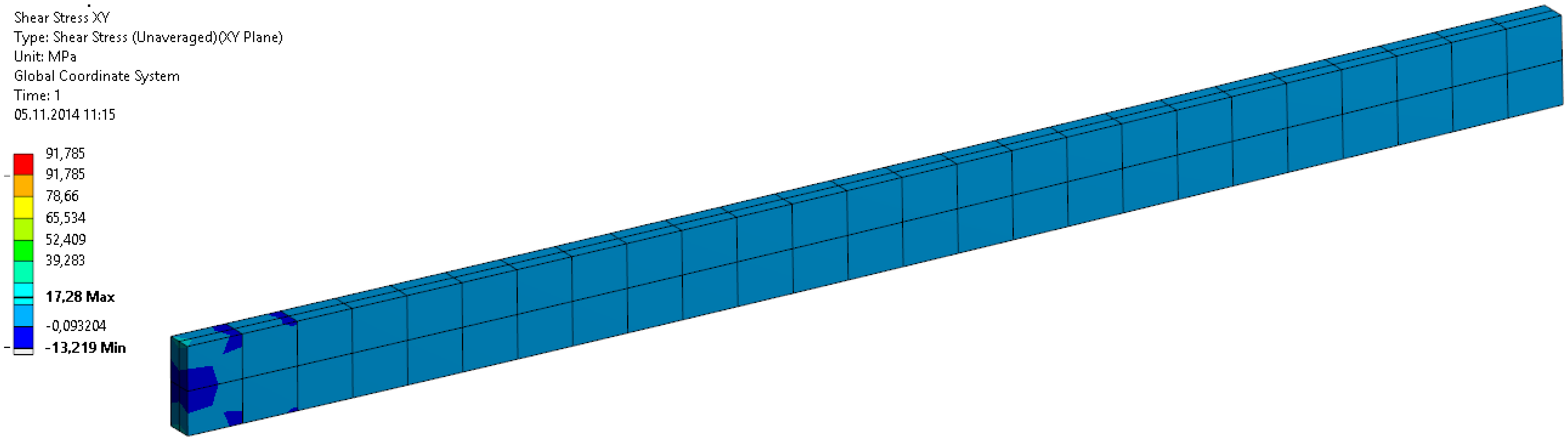


25x2x2 Hexhedra

Linear

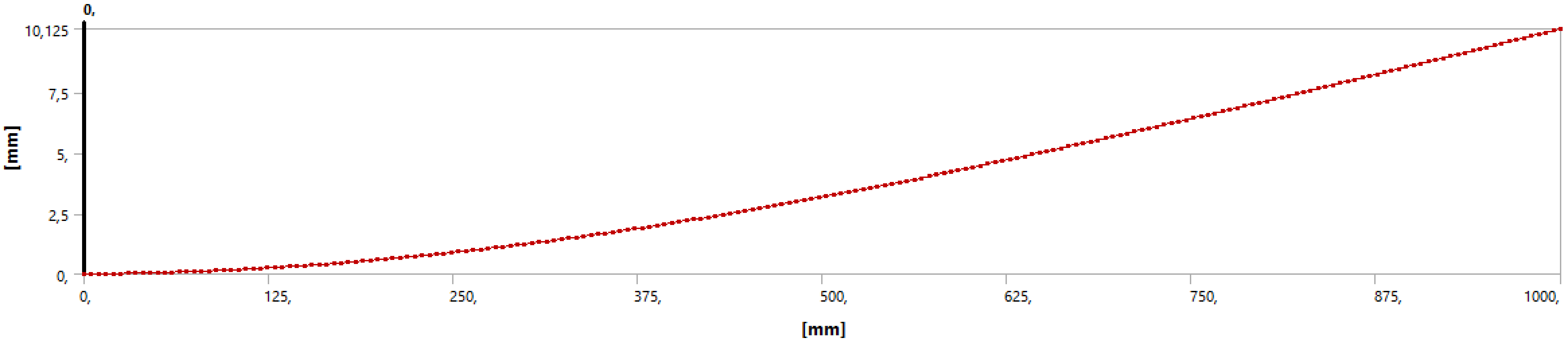


Quadratic

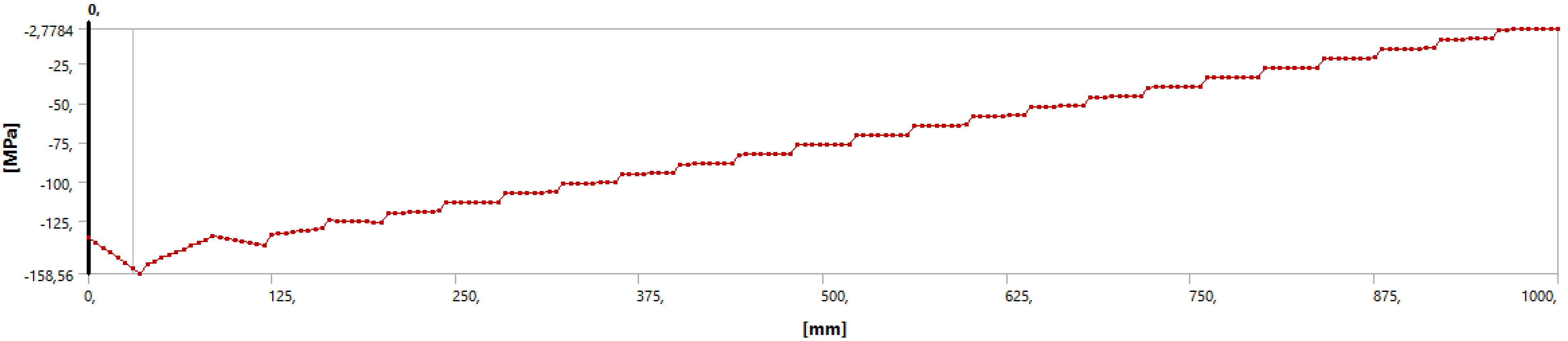


25x2x2 linear hexahedra

Total deformation

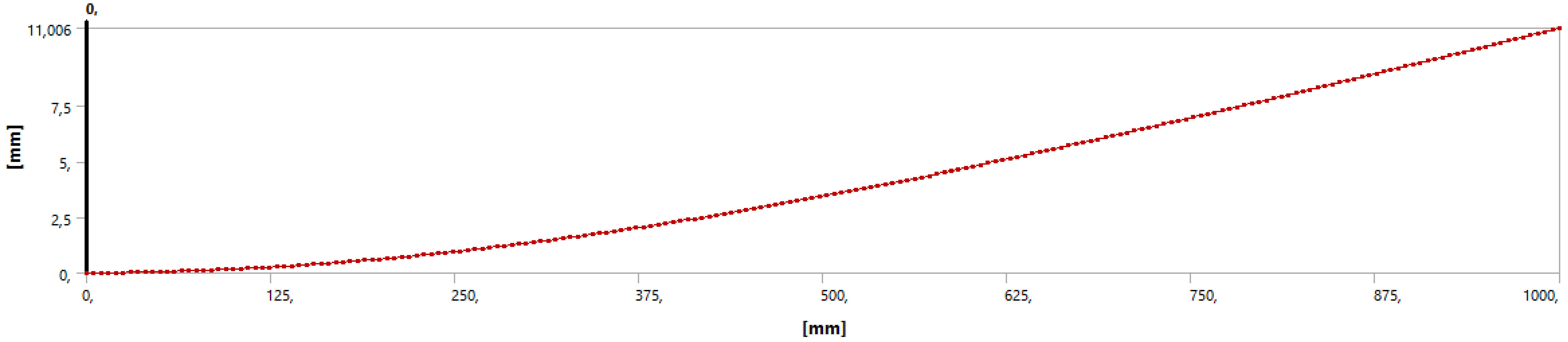


Normal stress, *x*

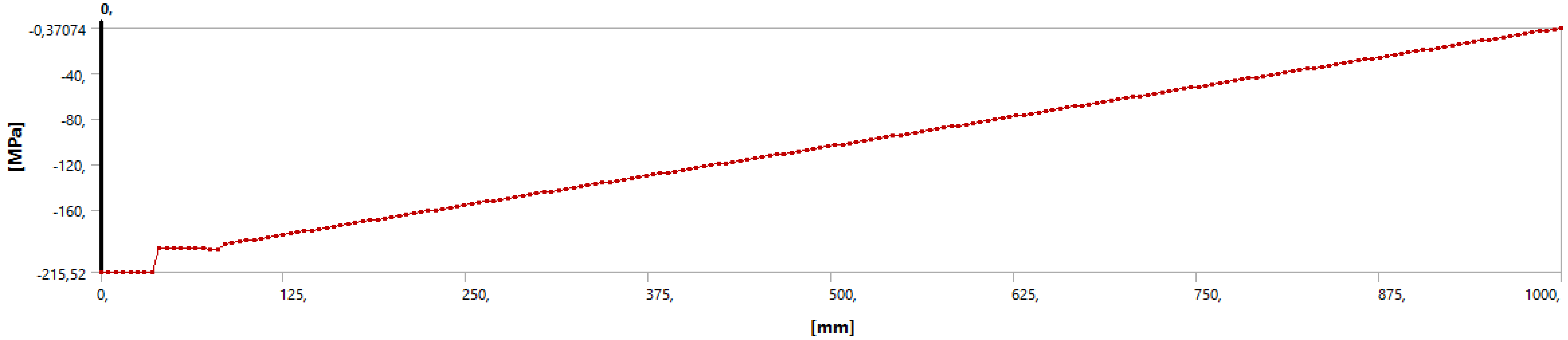


25x2x2 quadratic hexahedra

Total deformation

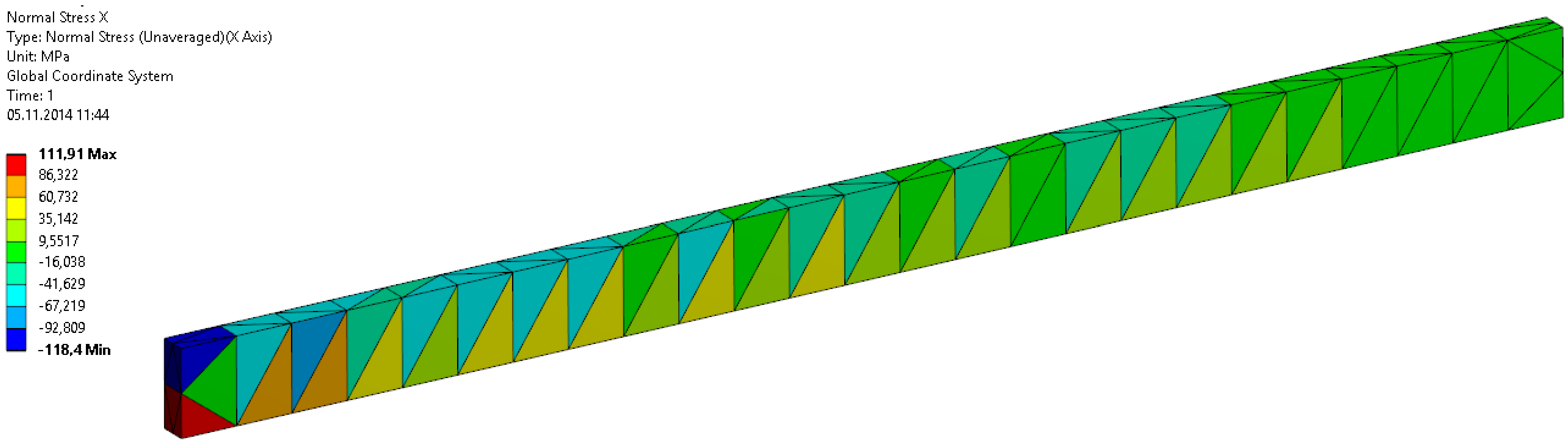


Normal stress, *x*

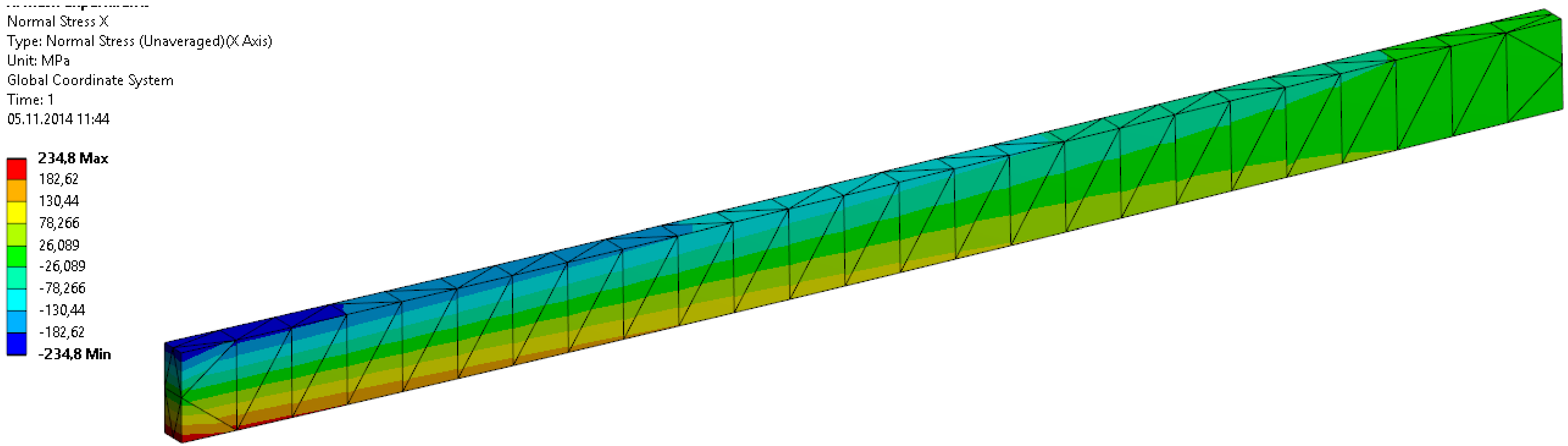


25x2x2 Tetrahedra

Linear

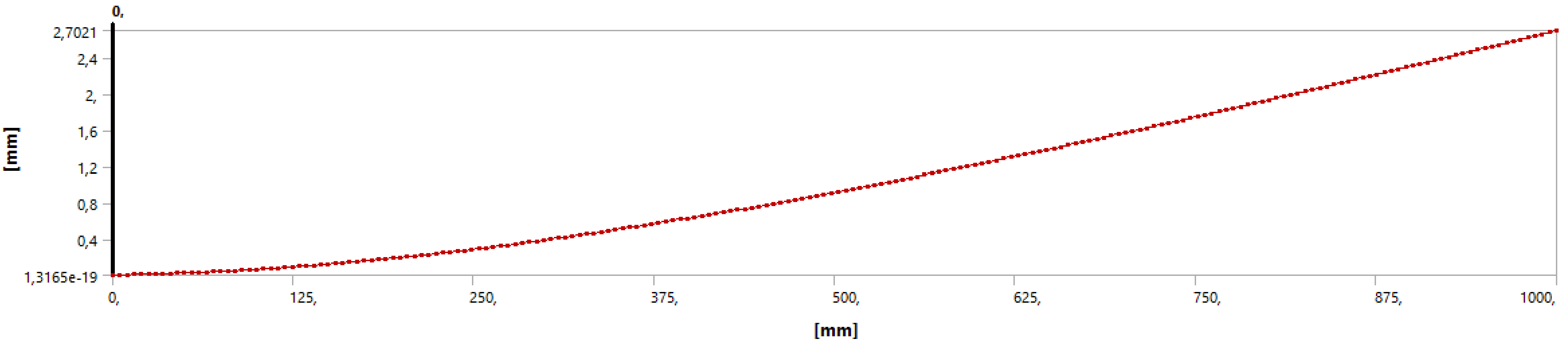


Quadratic

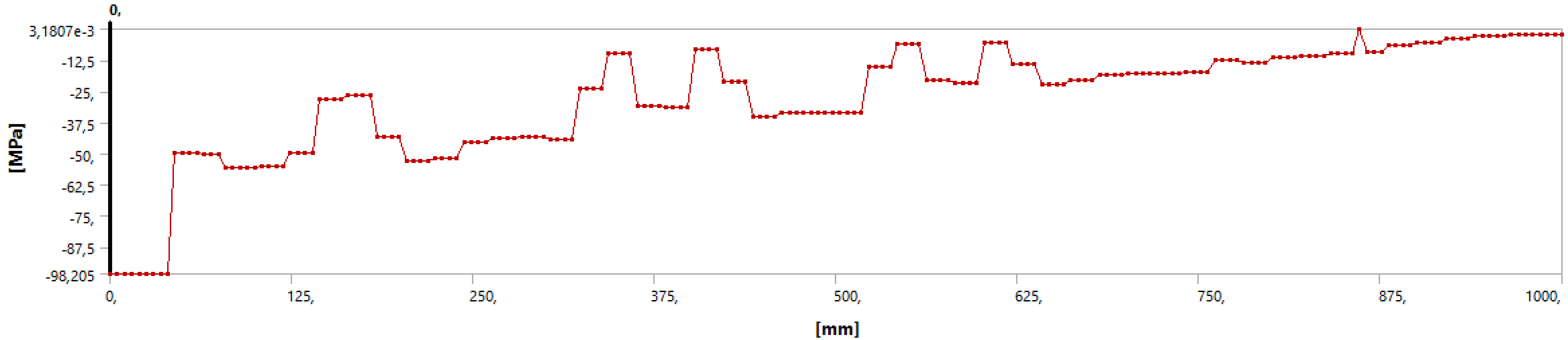


25x2x2 Linear Tetrahedra

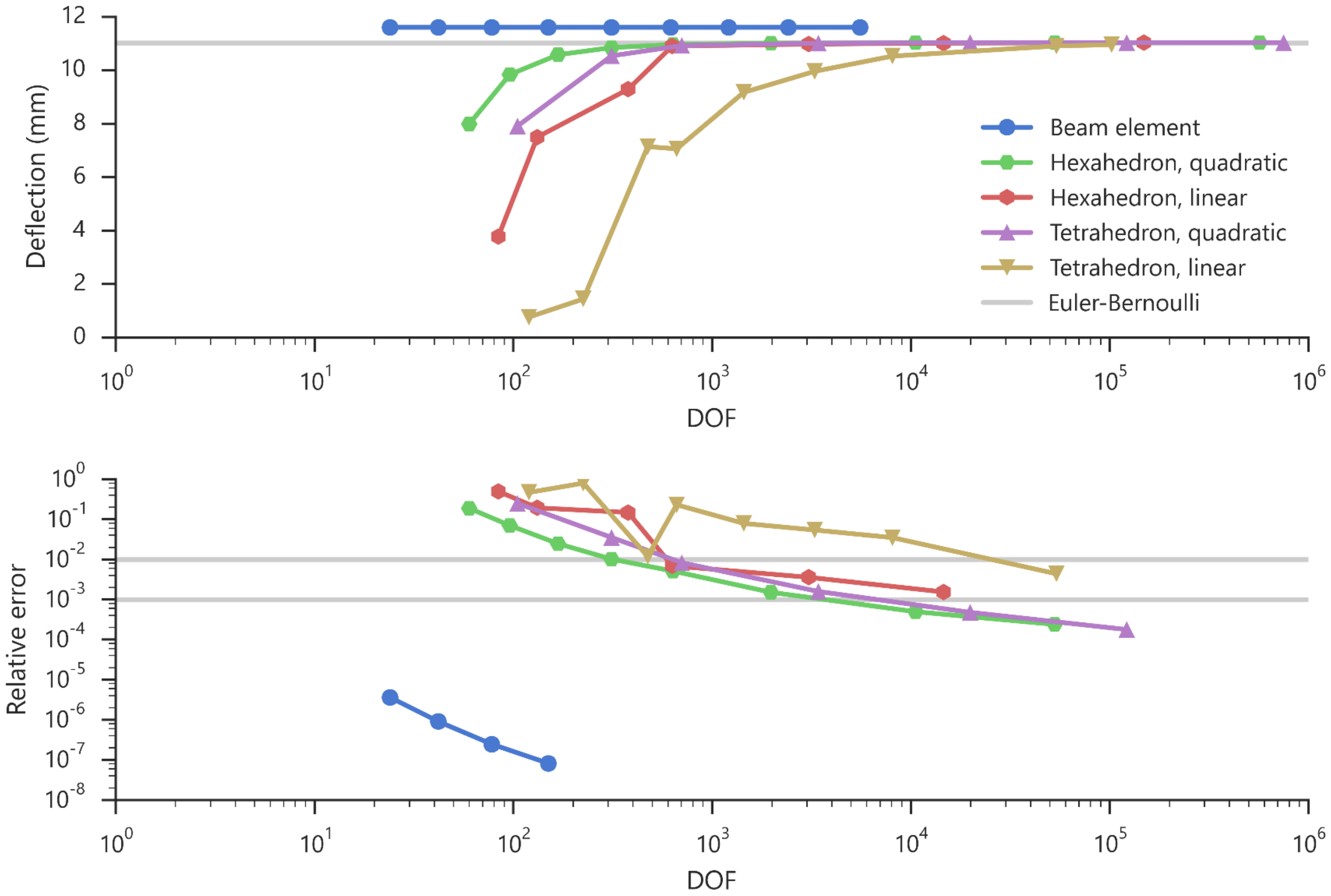
Total deformation



Normal stress, *x*

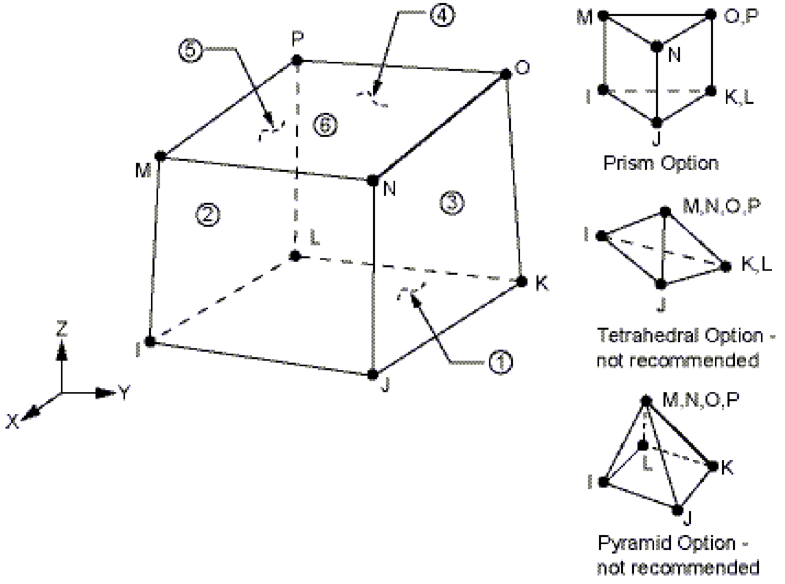


Convergence Analysis (3D)

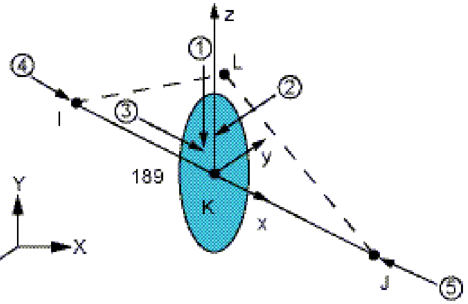


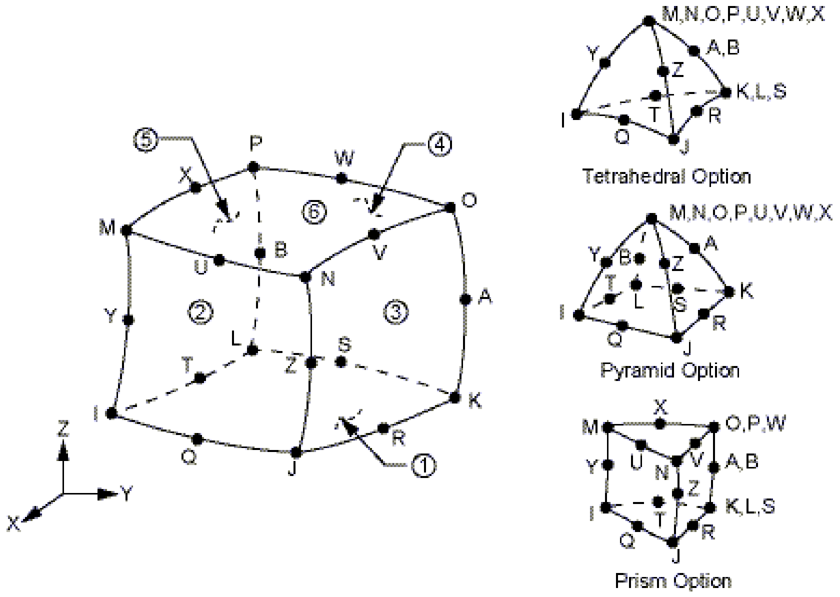
Convergence Analysis (3D)

Shape	Ansatz	DOFs	Deflection (mm)
Tetrahedron	linear	53922	10.91
Tetrahedron	quadratic	705	10.93
Hexahedron	linear	630	10.90
Hexahedron	quadratic	312	10.85
Timoshenko beam	quadratic	18	11.61



Euler-Bernoulli: $w_{\max} = \frac{Fl^3}{3EI} = 12\frac{Fl^3}{3Ebh^3} = 11.02\text{ mm}$



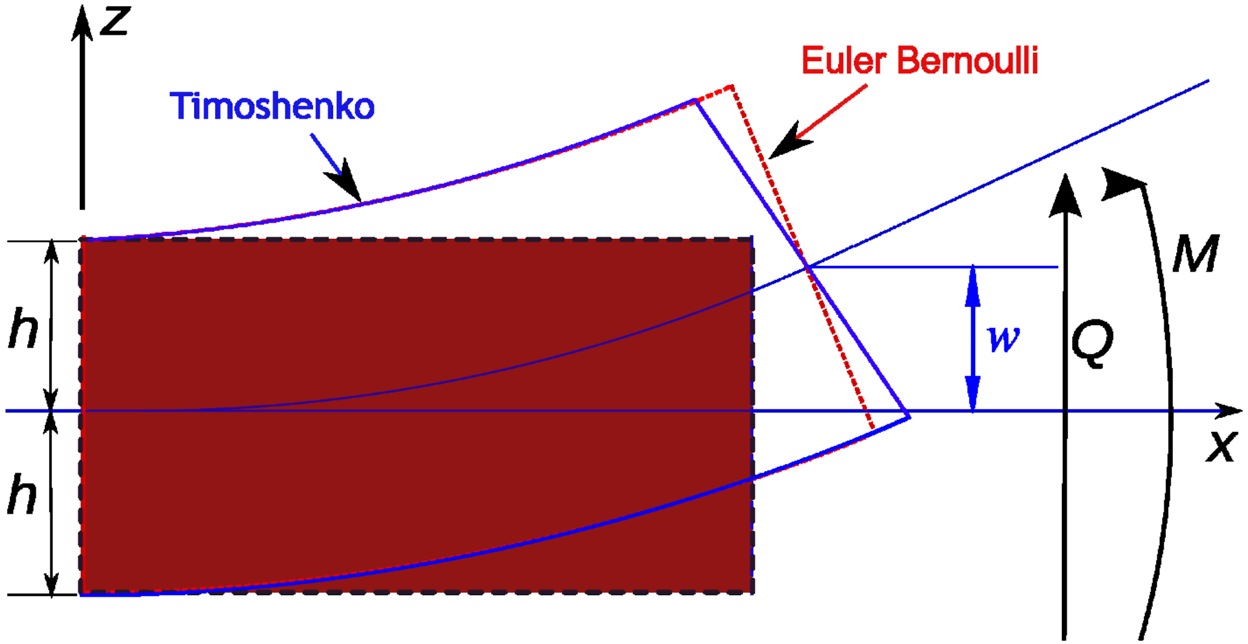


Timoshenko vs. Euler-Bernoulli

"The BEAM189 element is suitable for analyzing ***slender to moderately stubby/thick*** *beam structures.*

The element is based on Timoshenko beam theory which ***includes shear-deformation*** *effects."*

ANSYS 15.0 Documentation (Element Library)

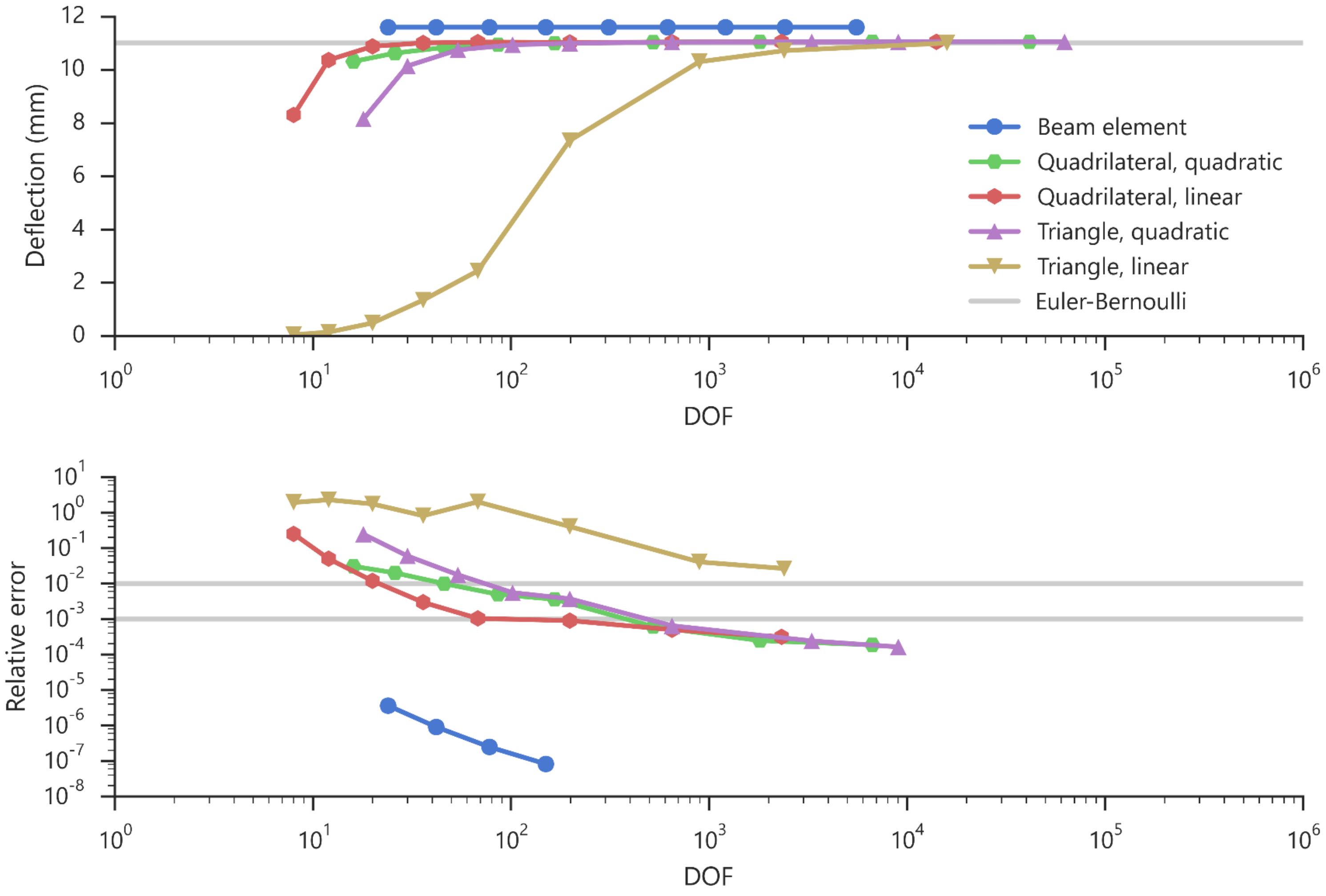


http://en.wikipedia.org/wiki/Timoshenko_beam_theory

$$w_{\max}^{\mathrm{EB}} = \frac{Fl^3}{3EI}$$

$$w_{\max}^{\mathrm{T}} = \frac{Fl}{\kappa AG} + \frac{Fl^3}{3EI}$$

Convergence Analysis (2D)



(Non-)Convergence of Max. Stress (3D)