

## CUSTOMER SUPPORT NOTE

# Nonlinear Implicit Dynamic Example for Impact Analysis

Note Number:	<b>CSN/LUSAS/1032</b>
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This support note is issued as a guideline only.



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## 1. Introduction

Impact analysis may be required to monitor cases when two bodies come together with some relative velocity. After incidence takes place, the two bodies will interact in a small contact area at the interface between them. The pressure in the contact area may results in permanent local deformation and consequent indentation.

At each instant during impact a resultant force due to contact pressure acts in opposite directions (action/reaction) on both bodies, thus resisting interpenetration. This force increases while the speed of the colliding bodies decreases, until the latter turns to zero. Then, the stored energy during compression may drive the two bodies apart until they completely separate.

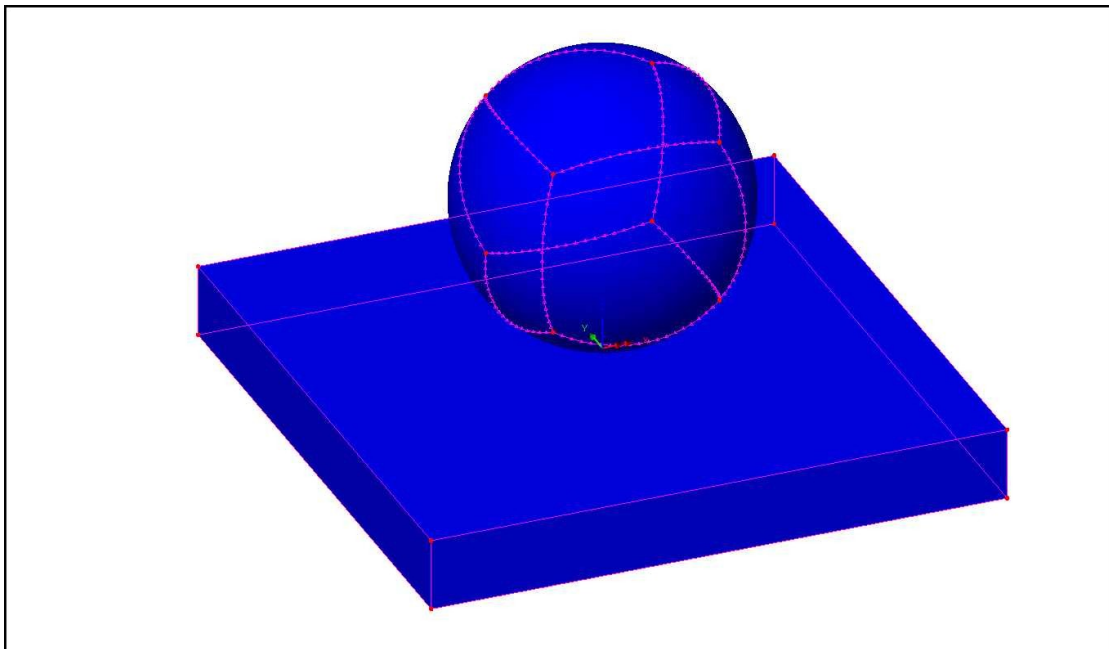
The initial velocity and hardness of the surfaces in contact affects directly the local deformations arising during impact; low speed collisions lead to small deformation in the contact area and hard bodies require small deformations to generate high contact pressures.

## 2. Description

### 2.1 Geometry - Volume Features

As an example, here a sphere of radius 0.025m is modelled in a small distance e.g. 0.01m from a cuboid of 0.40m x 0.40m x 0.05m.

Units used are N,m,kg,s,C



### 2.2 Mesh attributes

The vertical lines of the cuboid have a null mesh attribute with one division, while the rest of the model has six divisions in this simple test.

Stress hexahedral elements with a linear interpolation order (HX8M) are used throughout.

### 2.3 Material attributes

A linear ungraded concrete material is on the cuboid to represent a hard material

*Attributes > Material > Material Library*

Material Library

Material: Concrete

Grade: Ungraded

Properties

Young's modulus: 30.0E9

Poisson's ratio: 0.2

Density: 2.4E3

Thermal expansion: 10.0E-6

OK Cancel Apply Help

The ball is represented with a soft plastic material with Rayleigh damping. Providing a small hardening slope (about  $E/1000$ ) is recommended, as it can help overcome numerical difficulties in nonlinear models.

Isotropic

Using the following properties

☒ Plastic ☐ Creep ☐ Damage ☐ Shrinkage ☐ Viscous ☐ Two phase

Elastic Plastic

☒ Dynamic properties ☐ Thermal expansion

	Value
Young's modulus	200.0E6
Poisson's ratio	0.3
Mass density	2.0E3
Mass Rayleigh damping constant	1.0E-3
Stiffness Rayleigh damping constant	1.0E-3

Name: Soft Nonlinear Material (2)

Close Cancel Apply Help

Isotropic

Using the following properties

☒ Plastic ☐ Creep ☐ Damage ☐ Shrinkage ☐ Viscous ☐ Two phase

Elastic Plastic

Model: Stress potential

Stress potential type: Von Mises

Section shape: Circular hollow section

☐ Heat fraction

☒ Mass concrete ☐ Reinforced concrete

	Value
Initial uniaxial yield stress	5.0E6

☒ Hardening

☐ Total strain ☐ Plastic strain ☒ Hardening gradient

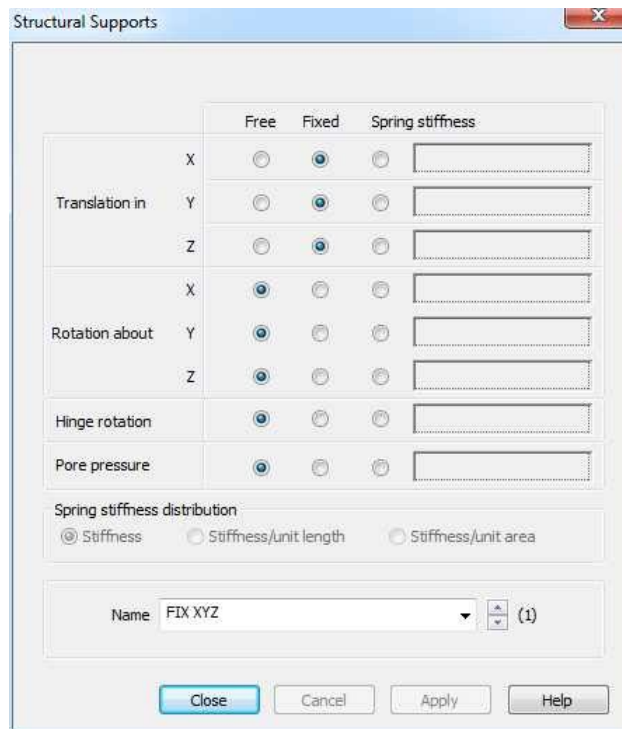
Tension		Compression	
	Slope	Plastic strain	
1	200.0E3	1.0E3	1
2			

Name: Soft Nonlinear Material (15)

Close Cancel Apply Help

## 2.4 Support attributes

Support attributes are assigned at the bottom surface of the cuboid.



Select the supported surface of the base volume and drag and drop the support attribute onto the model.

## 2.5 Loading attributes

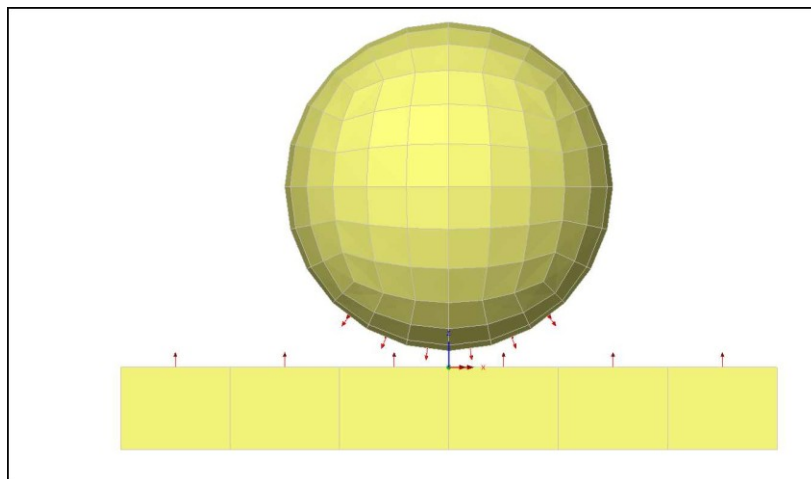
An initial velocity of -15m/sec is assigned onto the ball along the vertical axis.

*Attributes > Loading > Velocity*

## 2.6 Slideline attributes

A friction type slideline is used between the upper surface of the cuboid (master) and the lower surface of the ball (slave).

*Attributes > Slideline*



	Master stiffness scale	Slave stiffness scale	Coulomb friction coefficient	Zonal contact detection	Slide extension	Close contact
1	1.0	1.0	0.3	0.01	0.0	1.0E-3

☐ Temperature dependent  
☐ Pre-contact parameter  
☒ Contact cushioning parameter

Initial slideline type: Friction  
☐ Type changes during analysis  
 Type after change: No Friction  
 Changes at loadcase: 1: Loadcase 1

Rigid type: Non-rigid  
 Number of passes: 2  
 Geometric definition: Linear or Bi-linear

Name: Slideline (1)

Close Cancel Apply Help

A friction coefficient of 0.3 between the two colliding bodies was defined.

Contact cushioning can be used when convergence difficulties related to in-contact/out-of-contact chatter are experienced. Contact cushioning can help improve nonlinear convergence when chatter is encountered and the set of active contact nodes is continually changing, as in this case when the two bodies collide.

## 2.7 Nonlinear controls

Impact analyses are commonly performed using explicit elements, however here we use implicit elements with very small time steps to monitor the impact. Implicit elements have the extra advantage that equilibrium is guaranteed at the end of each time step and increment and thus the solution process is accurate. For explicit analysis however, since equilibrium is not accounted for, the solution may increasingly drift away from the true nonlinear load-deformation curve as the solution progresses.

The analysis setting is nonlinear implicit dynamics with initial time step of 0.1E-3sec and total duration is 0.01sec. 100 time steps are monitored and defined in the settings.

**Nonlinear & Transient**

<b>Incrementation</b> <input checked="" type="checkbox"/> Nonlinear Incrementation: <input type="text" value="Manual"/> Starting load factor: <input type="text" value="0.1"/> Max change in load factor: <input type="text" value="0.0"/> Max total load factor: <input type="text" value="1.0"/> <input checked="" type="checkbox"/> Adjust load based on convergence Iterations per increment: <input type="text" value="4"/> <input type="button" value="Advanced..."/>		<b>Solution strategy</b> <input type="checkbox"/> Same as previous loadcase Max number of iterations: <input type="text" value="12"/> Residual force norm: <input type="text" value="0.1"/> Incremental displacement norm: <input type="text" value="1.0"/> <input type="button" value="Advanced..."/>	
<input checked="" type="checkbox"/> Time domain Initial time step: <input type="text" value="0.1E-3"/> Total response time: <input type="text" value="0.01"/> <input type="checkbox"/> Automatic time stepping <input type="button" value="Advanced..."/>		<b>Incremental LUSAS file output</b> <input type="checkbox"/> Same as previous loadcase Output file: <input type="text" value="1"/> Plot file: <input type="text" value="1"/> Restart file: <input type="text" value="0"/> Max number of saved restarts: <input type="text" value="0"/> Log file: <input type="text" value="1"/> History file: <input type="text" value="1"/>	
Common to all Max time steps or increments: <input type="text" value="100"/>			
<input type="button" value="OK"/> <input type="button" value="Cancel"/> <input type="button" value="Help"/>			

## 2.8 Creating contours animation

After the analysis runs, Mesh and Geometry layers are turned off, while Deformed mesh and Contours layers are turned on. Deformed mesh must have a scale factor of 1 specified to avoid misleading display of deformations.

**Properties**

Contour Results | Contour Display | Contour Range | Seed Colors

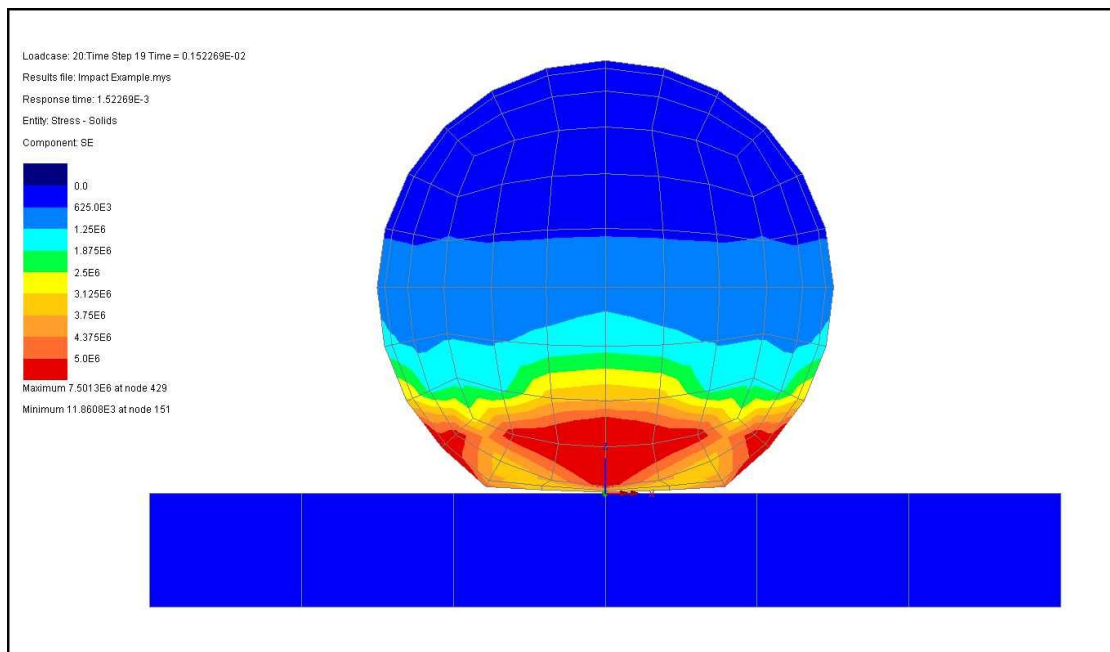
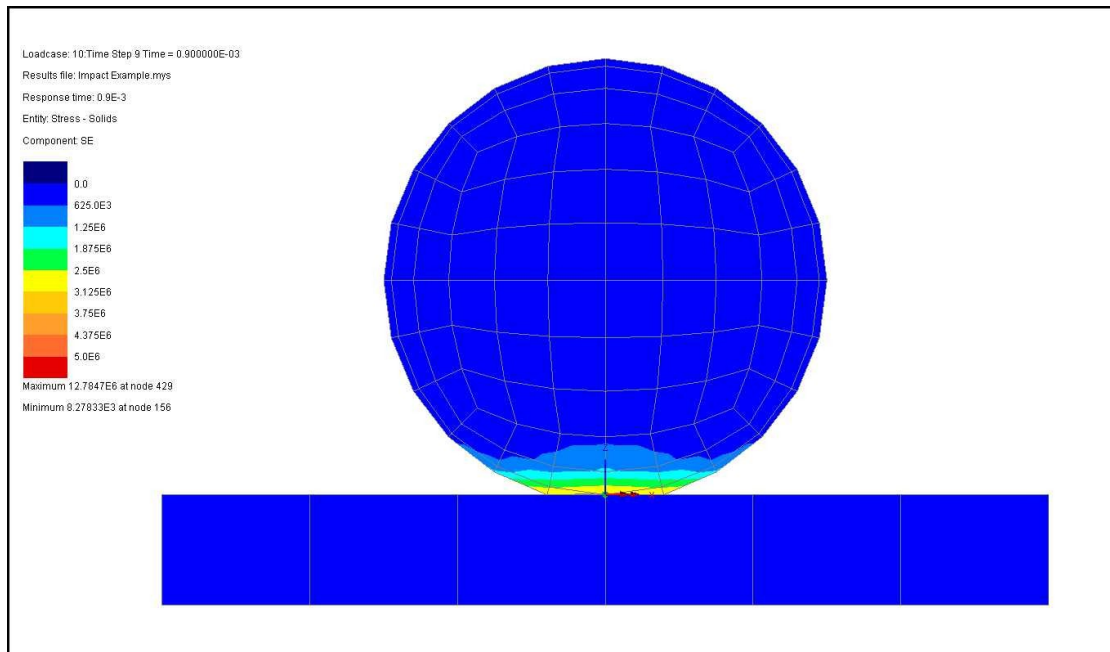
Entity:   
 Component:

☐ Display on slice(s)  
☐ Draw in slice local direction

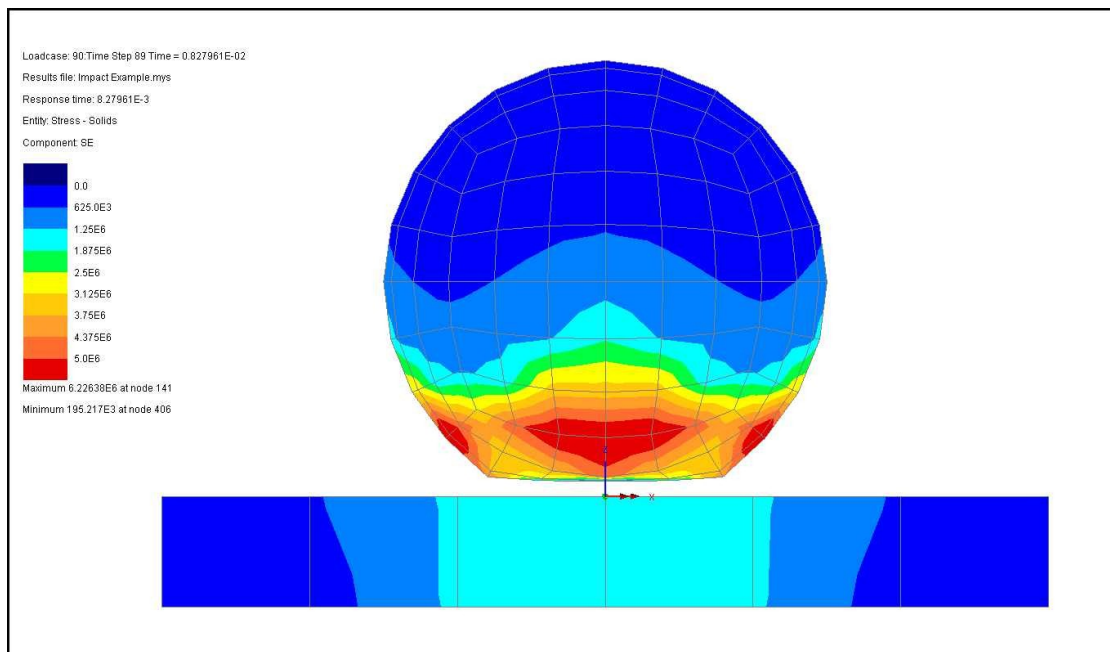
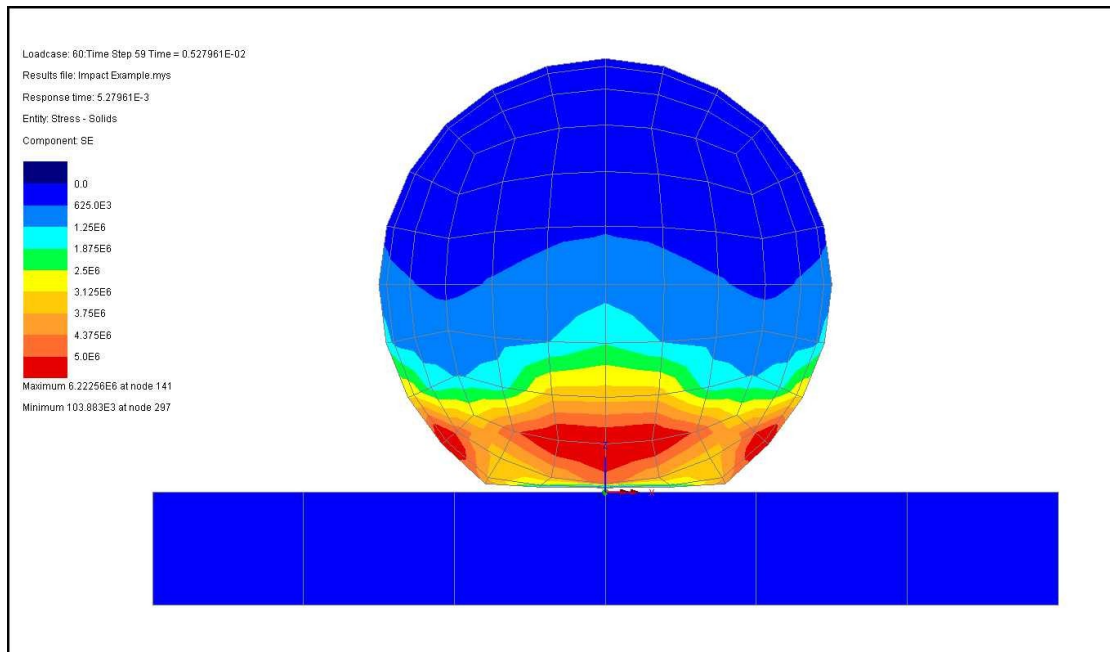
Create an animation of the changing contours for all time steps of the analysis.

*Utilities > Animation Wizard*

Following the deformed mesh and contours at different time steps are shown. As the ball is much softer than the cuboid it deforms until it bounces back as shown in the following screenshots.







An animation of the repose is provided along with a working model in the downloaded zip file.

## 2.9 Creating velocity vs time graph

Another way to monitor the response of the model over time is to create a velocity vs time graph of a contact node of the two surfaces.

Select a node on the ball ( say node 81) and follow the steps below:

*Utilities > Graph Wizard*

Graph Wizard

Type of graph dataset to generate

☒ Time history  
☐ Fourier expansion  
☐ Modal expansion  
☐ Load curve  
☐ Variation  
☐ Specified datasets  
☐ Thermal surfaces  
☐ Sidelines (assigned to lines)

< Back   Next >   Cancel   Help

Time History Graph - X Attribute

Results

Entity data  
☐ Nodal  
☐ Gauss point  
☒ Named  
☐ Element  
☐ Previously defined

Sample loadcases  
☒ Loadcases  
☒ All  
  
☐ History files

< Back   Next >   Cancel   Help

Time History Graph - X Attribute

Named data

Data: Response time

< Back   Next >   Cancel   Help

Time History Graph - Y Attribute

Results

Entity data  
☒ Nodal  
☐ Gauss point  
☐ Named  
☐ Element  
☐ Previously defined

Sample loadcases  
☐ Loadcases  
☒ All  
  
☐ History files

< Back   Next >   Cancel   Help

Time History Graph - Y Attribute

Nodal data

Entity: Velocity  
Component: VZ  
 None

Surface:   
Extent: Specified single node  
Specify node: 81

Selected nodes  
☒ Sum   ☐ Average  
81

< Back   Next >   Cancel   Help

Display Graph

Display  
☒ Create new graph  
☐ Add to existing graph  
☐ Do not display now

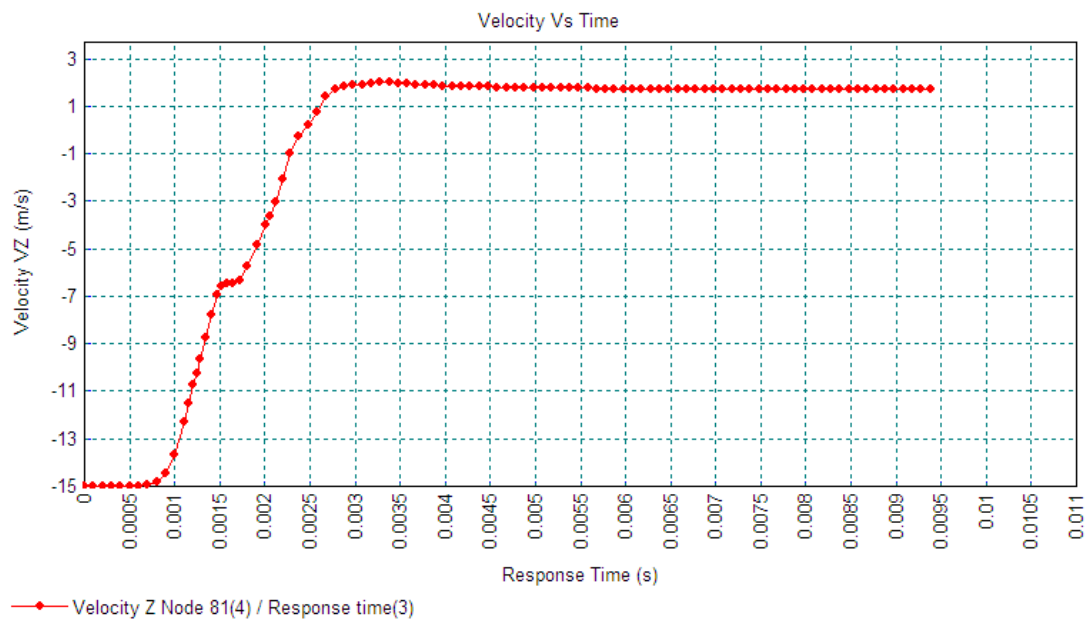
Title: Velocity vs Time  
X: Response time (s)  
Y: Velocity VZ (m/s)

X scale  
☒ Automatic   ☐ Manual  
min: 0.0   max: 1.0  
☐ Use logarithmic scale

Y scale  
☒ Automatic   ☐ Manual  
min: 0.0   max: 1.0  
☐ Use logarithmic scale  
Scale factor: 1.0

☒ Show grid   ☒ Show symbols   ☒ Corner labels

< Back   Finish   Cancel   Help



The graph depicts that after  $6.0 \times 10^{-4}$  second the two parts of the model come in contact, hence the value of the vertical velocity increases gradually and the velocity of this node changes direction at 0.0024 second.