Nonlinear Vibrations of Aerospace Structures

Tutorial 01

Introduction to NI2D

Teaching Assistant

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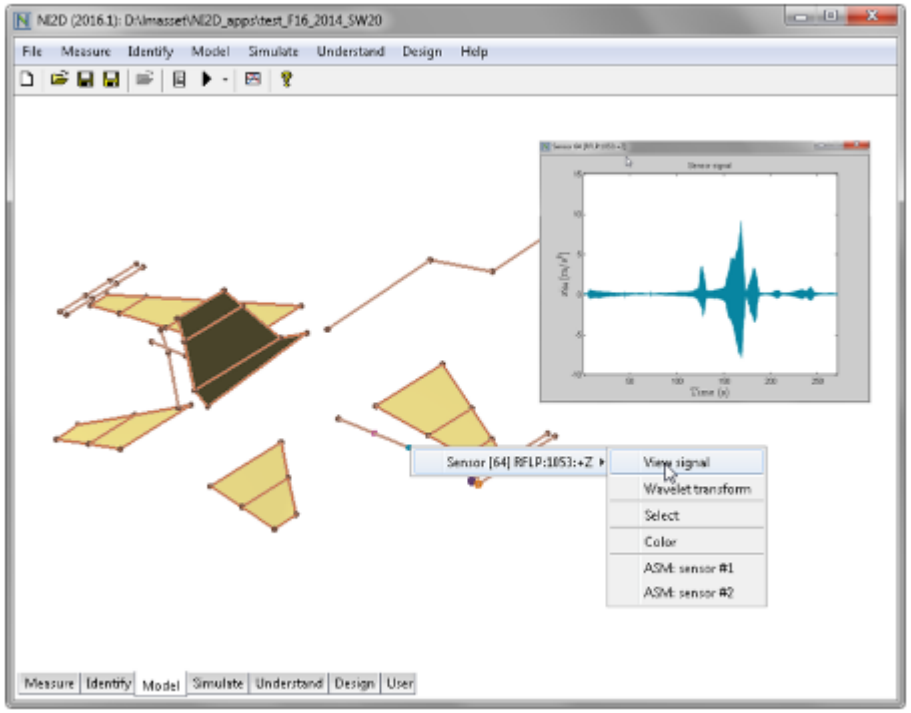
Tutorials and Project on the NI2D Software

Check www.nolisys.com

You'll get free access to the NI2D software until 31/03/2022.

Matlab environment; stand alone .exe.

Nonlinear Identification to Design
Software



NI2D Philosophy

Nonlinear Identification to Design

- *A prototype of the structure is available:*

→ Test it, identify the nonlinearities and upgrade the linear FEM.

- *A priori knowledge about the nonlinearities is available:*

→ Load the linear FEM into NI2D and implement the nonlinearities using NI2D elements library.

How To Read the Slides

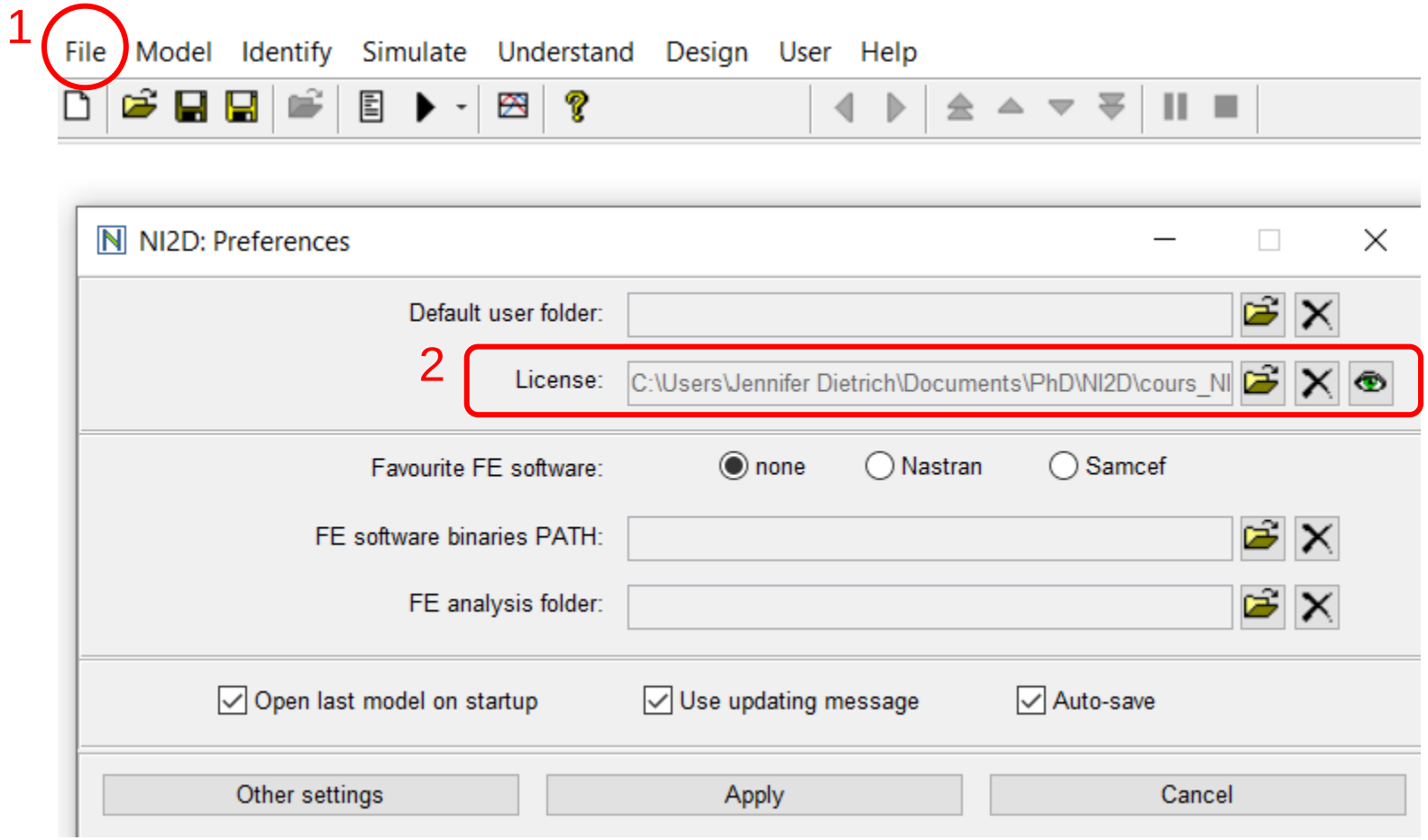
Click Here

Change parameters here

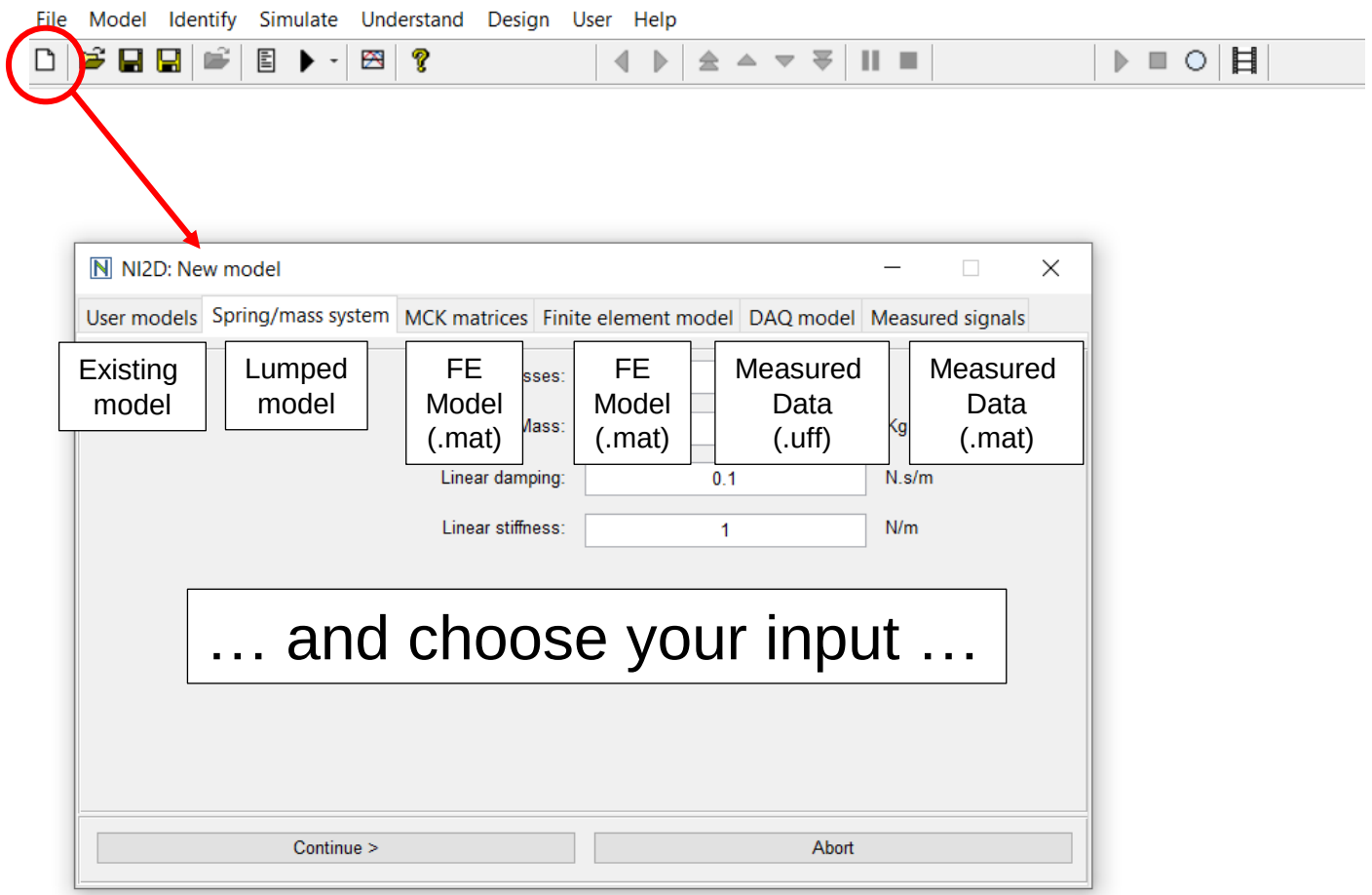
Comments

Get Started with NI2D

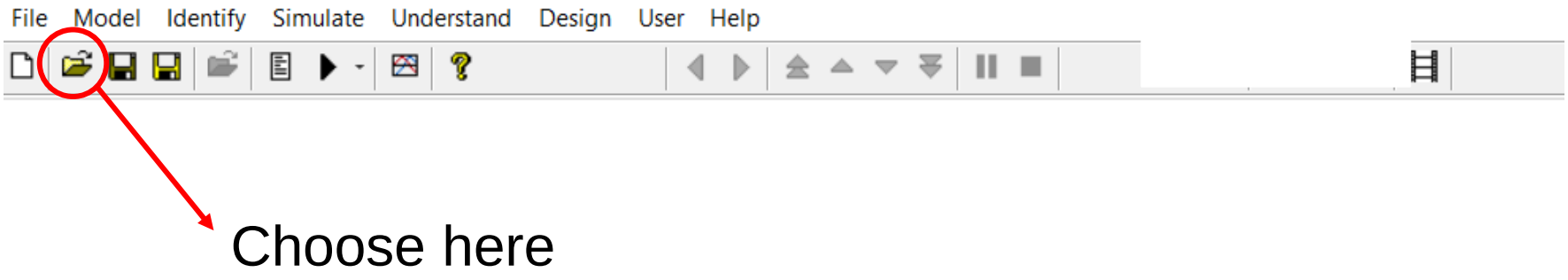
Launch NI2D and activate your license under *Preferences* …



Create a New Model



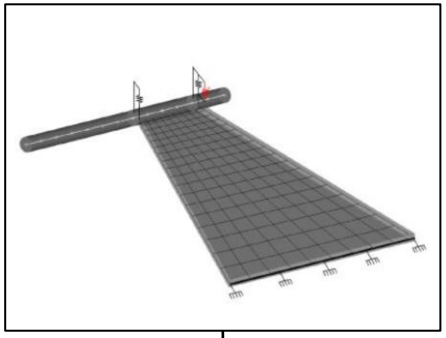
Open an existing model



The Different Solvers

VIBRATION MEASUREMENTS

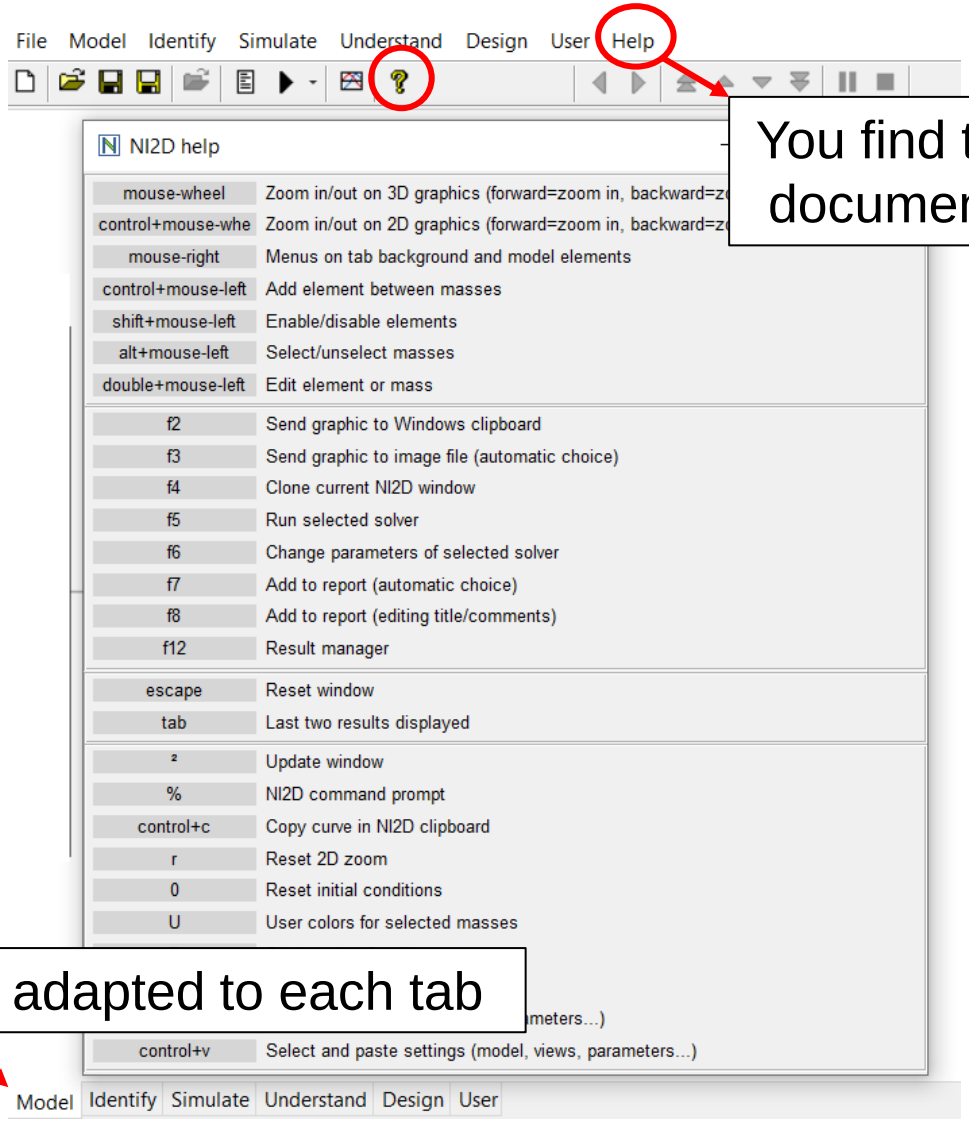
LINEAR FE-MODEL



MEASURE → IDENTIFY → HYBRID MODELLING → UNDERSTAND → DESIGN

Model | Identify | Simulate | Understand | Design

Need Help?



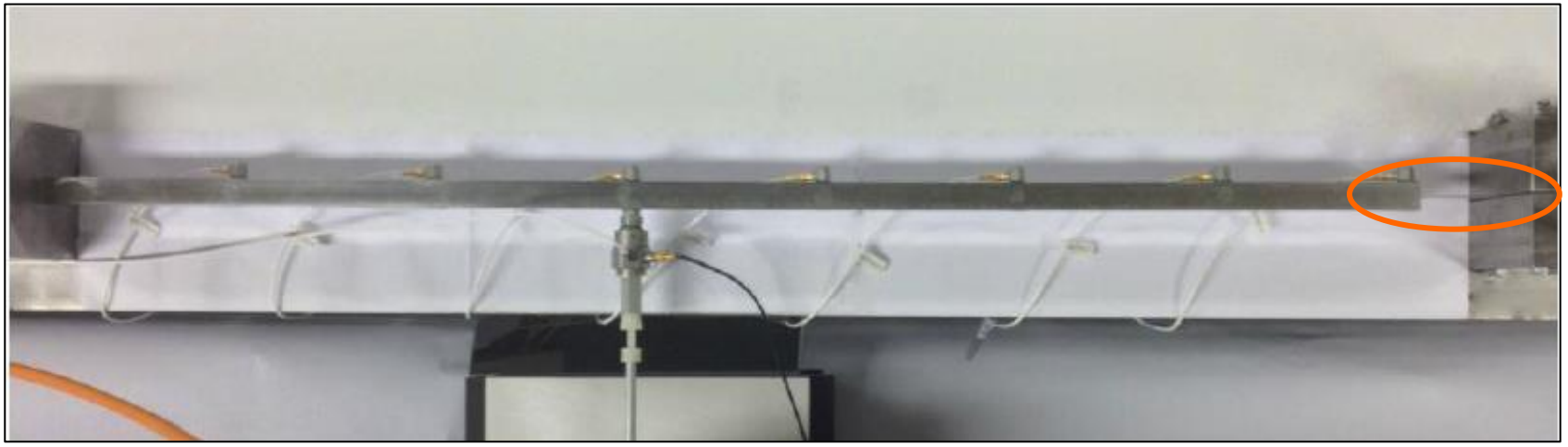
You find the software documentation here

The help menu is adapted to each tab

Launch Your First Numerical Simulation

Consider a Thin Short Beam …

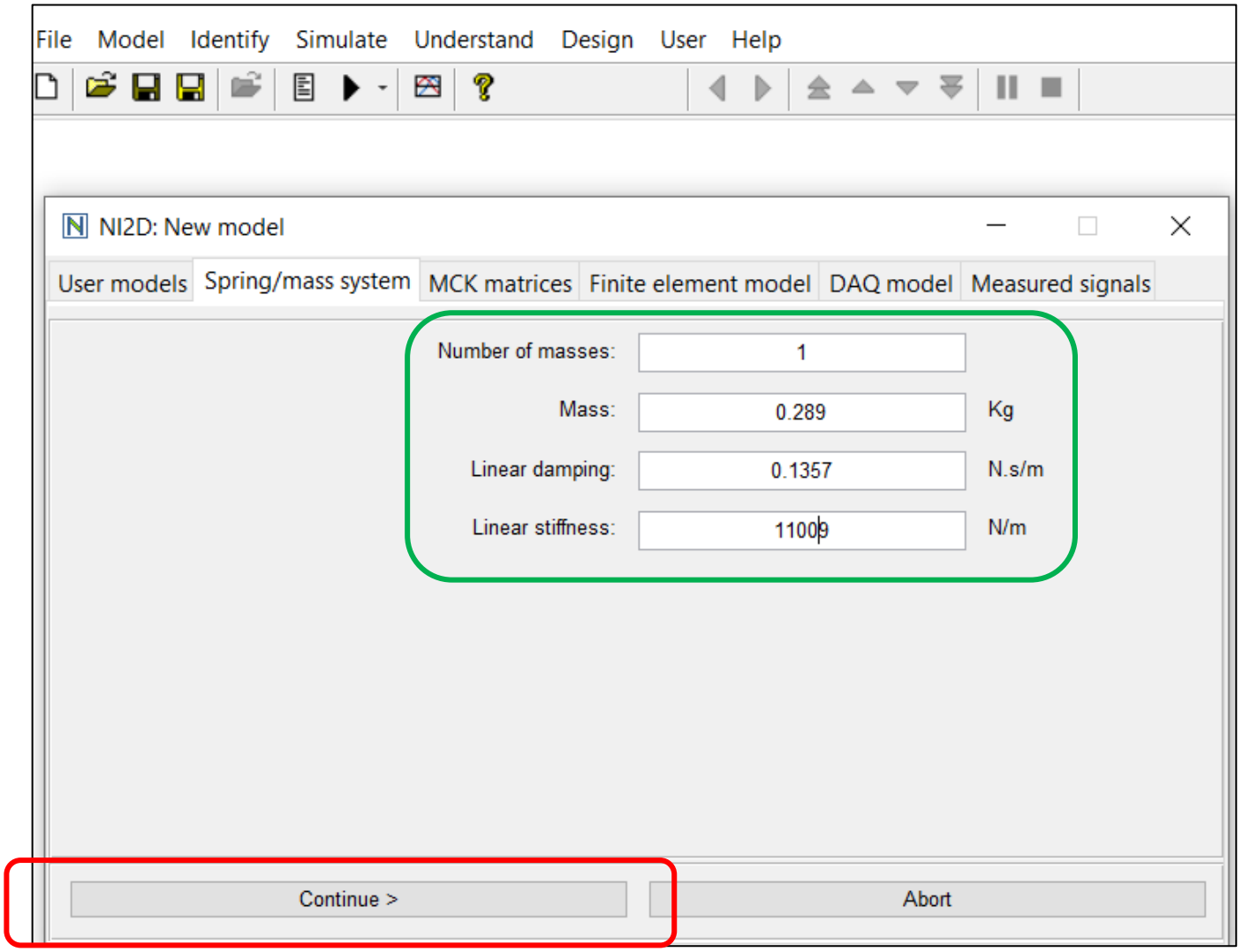
… connected to a cantilever beam (ECL benchmark)



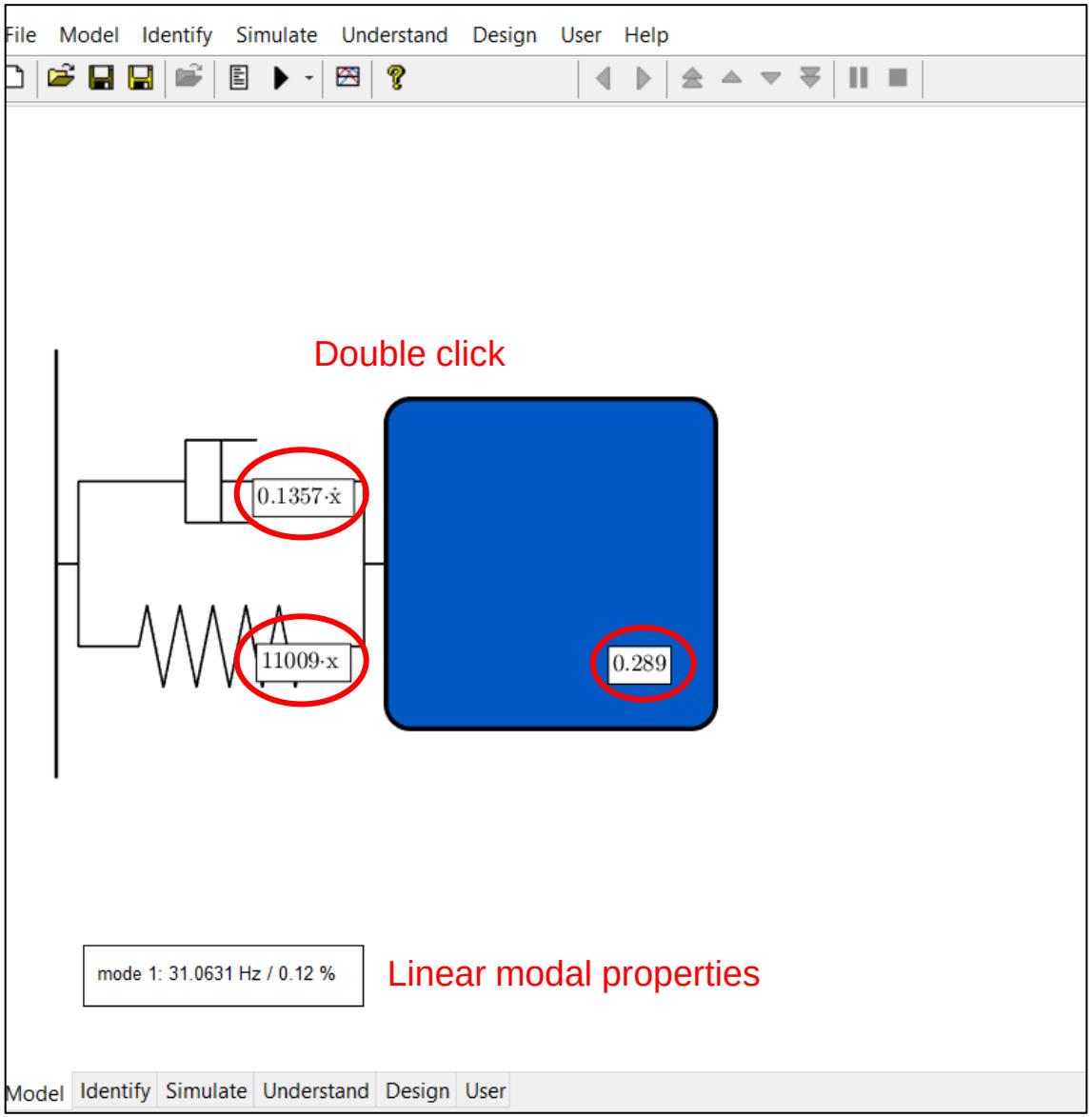
Linear model identified at low level (31 Hz, 0.12%):

$$0.289\ddot{x} + 0.1357\dot{x} + 11009x = F\sin\omega t$$

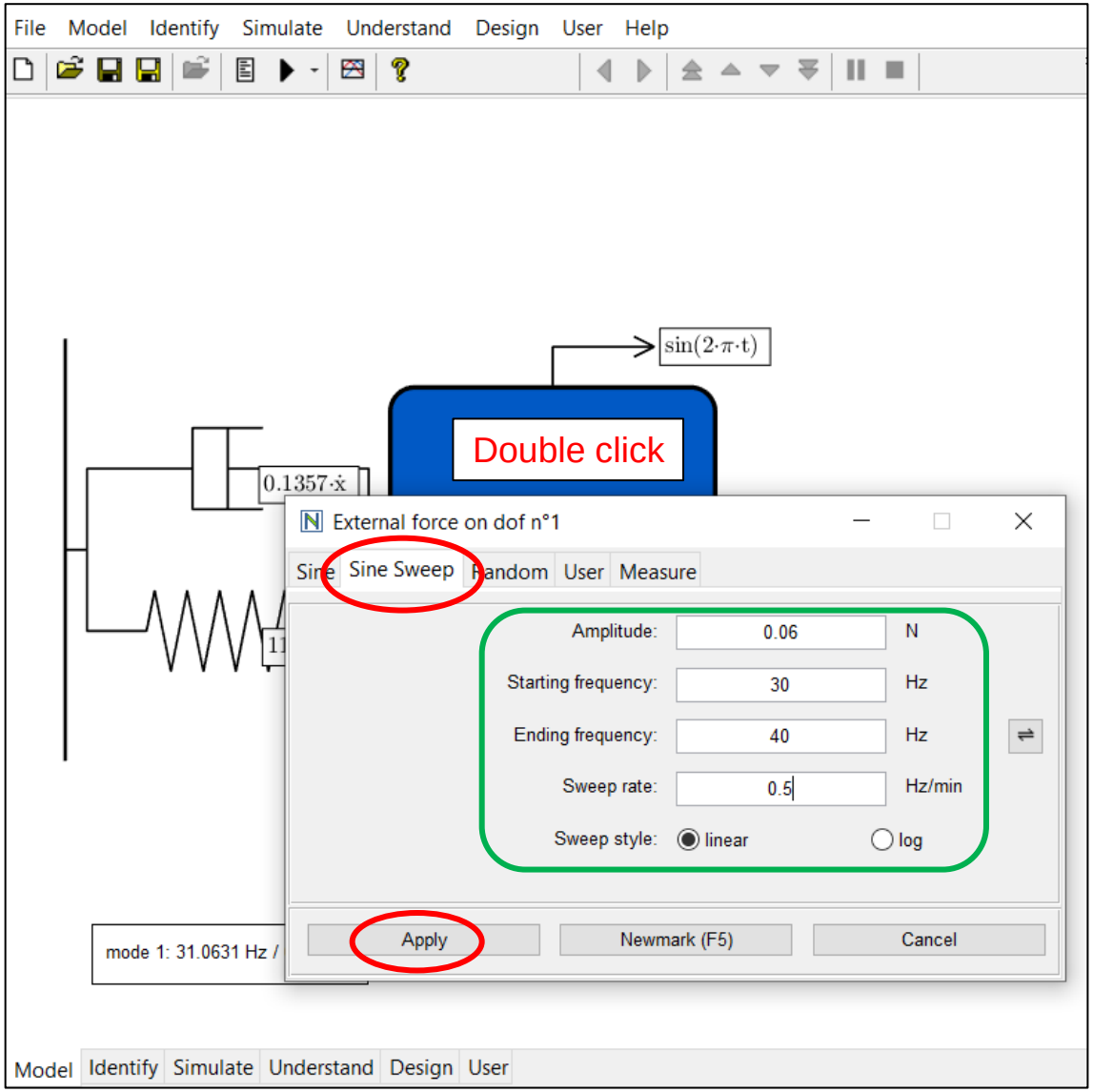
Create a New Model: 1 DOF Linear Oscillator



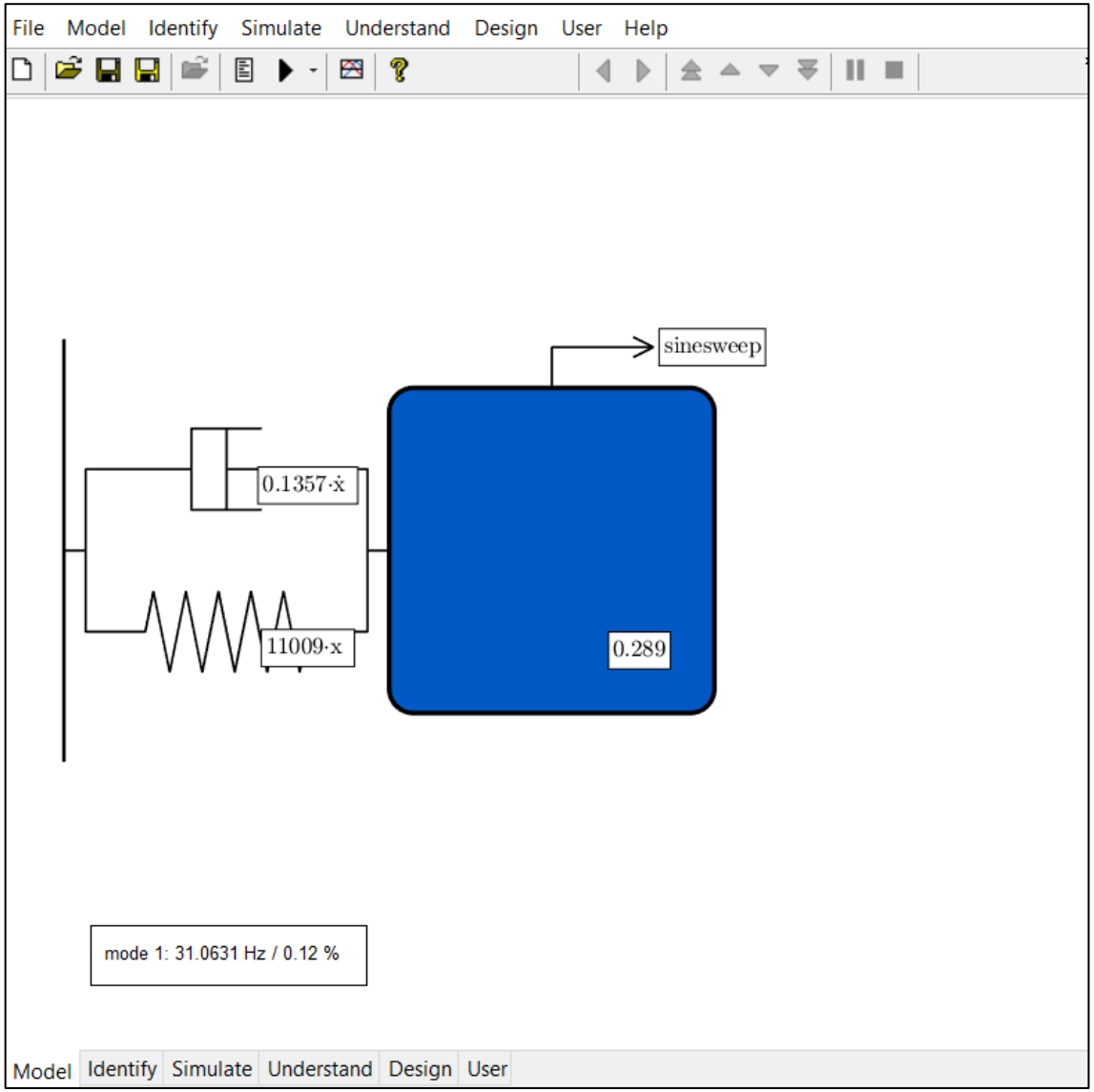
You Can Change the Coefficients Anytime …



Add an External Force

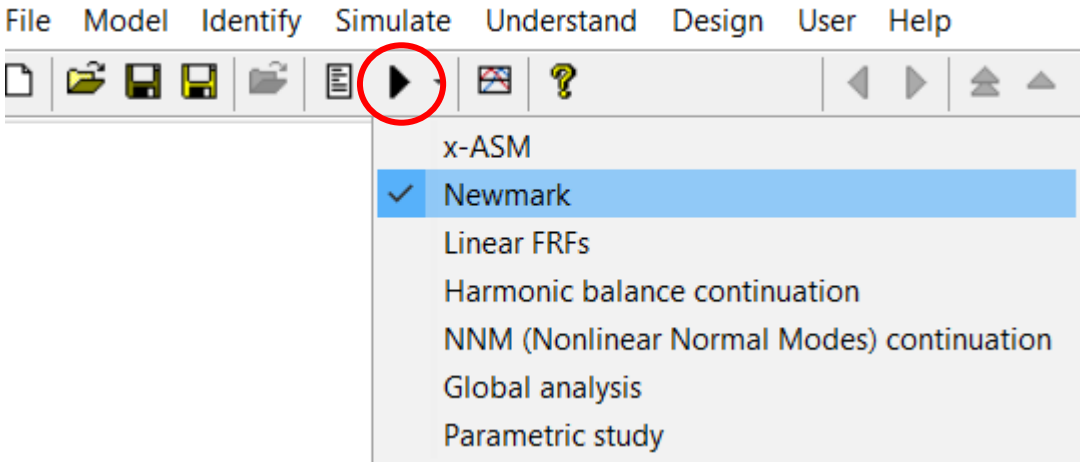


The Final Linear Model

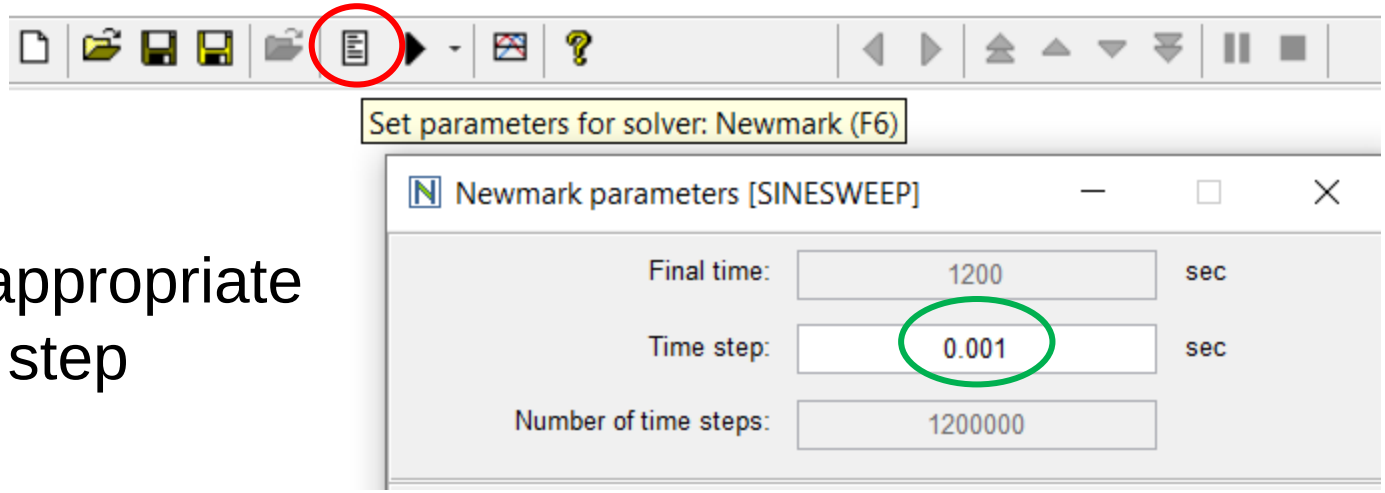


Calculate the Time Response with Newmark

1.



2.

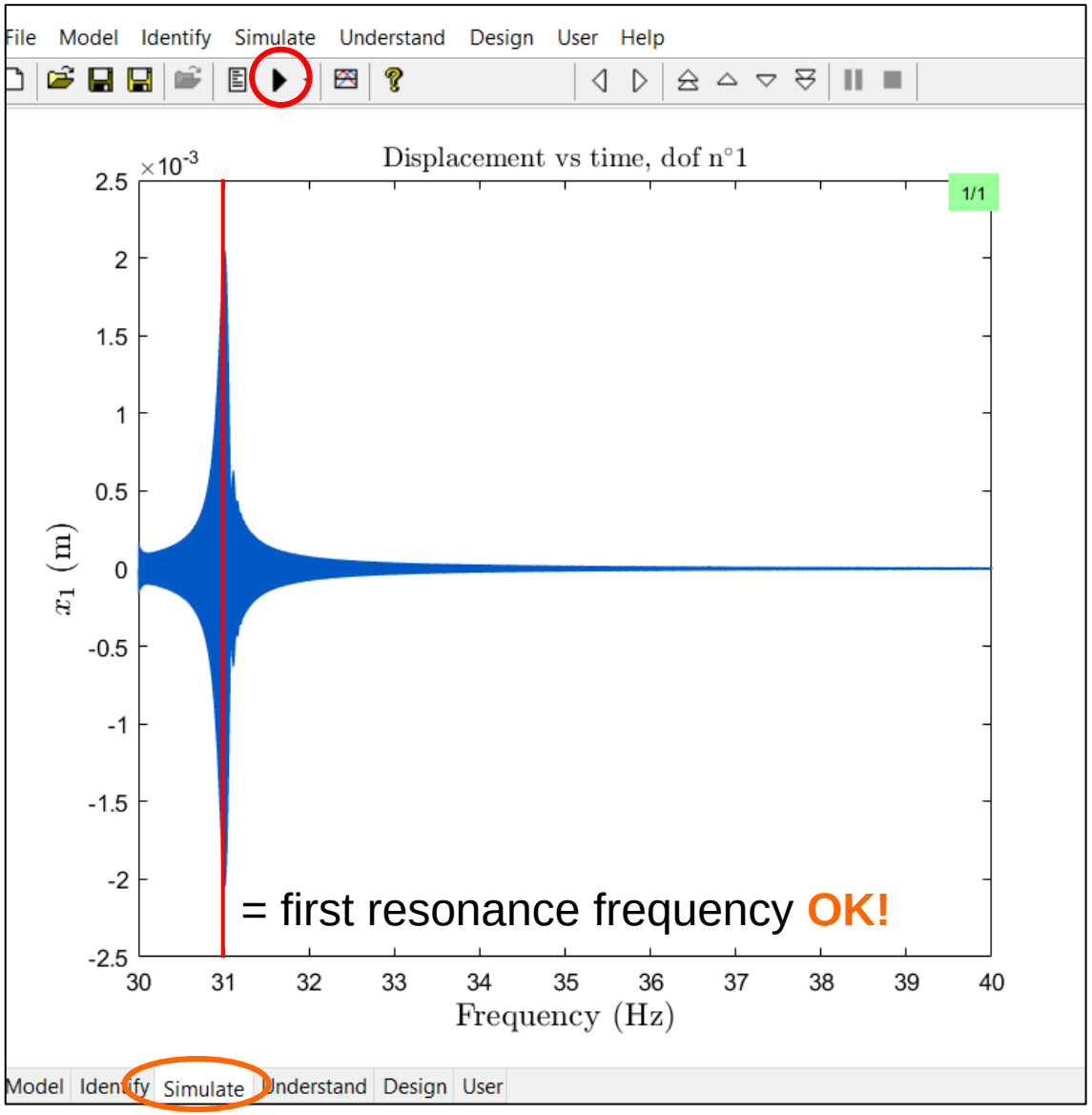


Select an appropriate time step

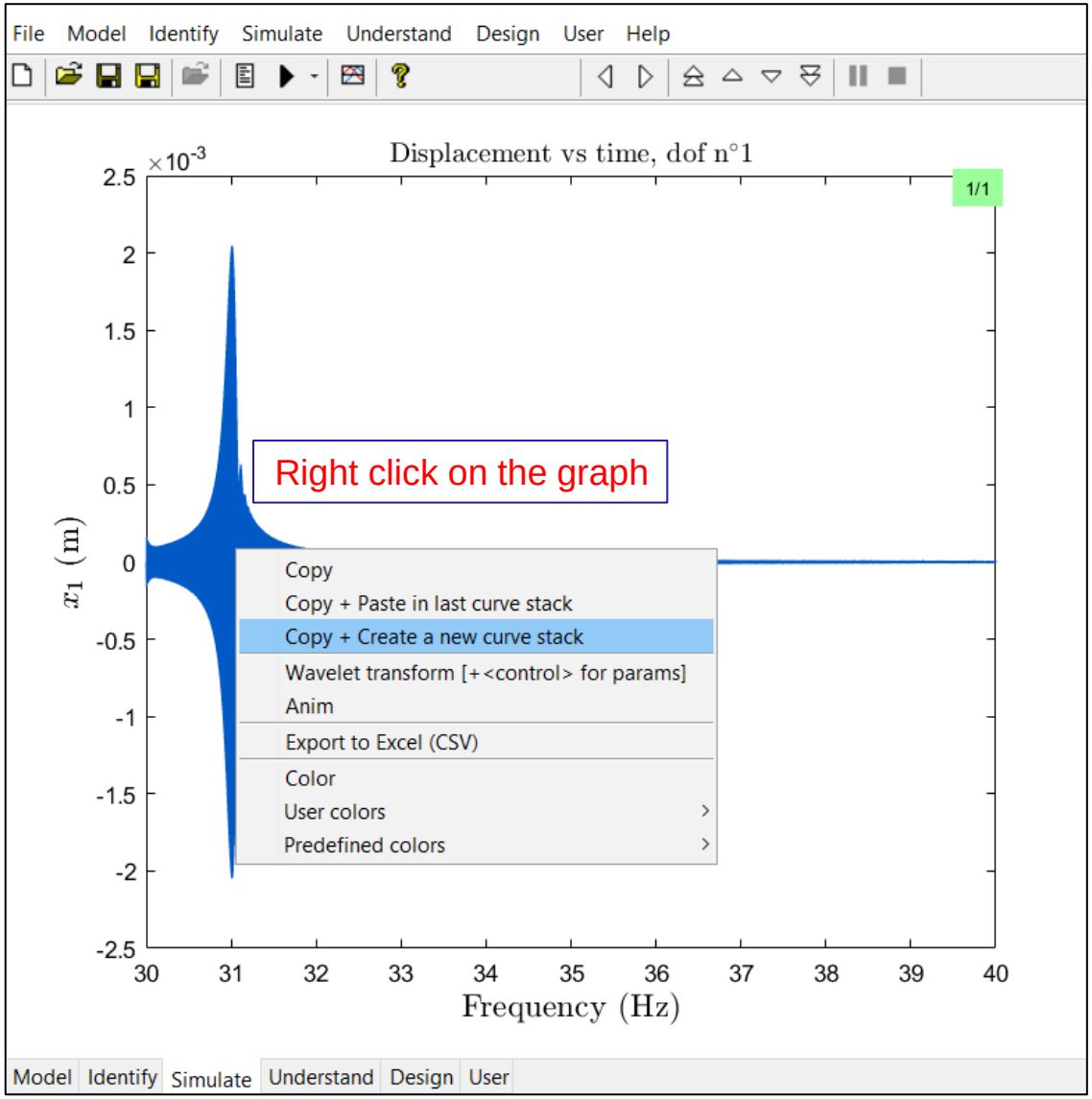
How to Choose the Right Sampling Frequency?

			Stability limit	**Accuracy** Amplitude error	**Accuracy** Periodicity error
Algorithm	γ	β	$\omega\, h$	$\rho\, -1$	$\frac{\Delta T}{T}$
Purely explicit	0	0	0	$\frac{\omega^2 h^2}{4}$	$-$
Central difference	$\frac{1}{2}$	0	2	0	$-\frac{\omega^2 h^2}{24}$
Fox & Goodwin	$\frac{1}{2}$	$\frac{1}{12}$	2.45	0	$O(h^3)$
Linear acceleration	$\frac{1}{2}$	$\frac{1}{6}$	3.46	0	$\frac{\omega^2 h^2}{24}$
Average constant acceleration	$\frac{1}{2}$	$\frac{1}{4}$	∞	0	$\frac{\omega^2 h^2}{12}$
Average constant acceleration (modified)	$\frac{1}{2}+\ \alpha$	$\frac{(1+\ \alpha)^2}{4}$	∞	$\alpha - \frac{\omega^2 h^2}{2}$	$\frac{\omega^2 h^2}{12}$

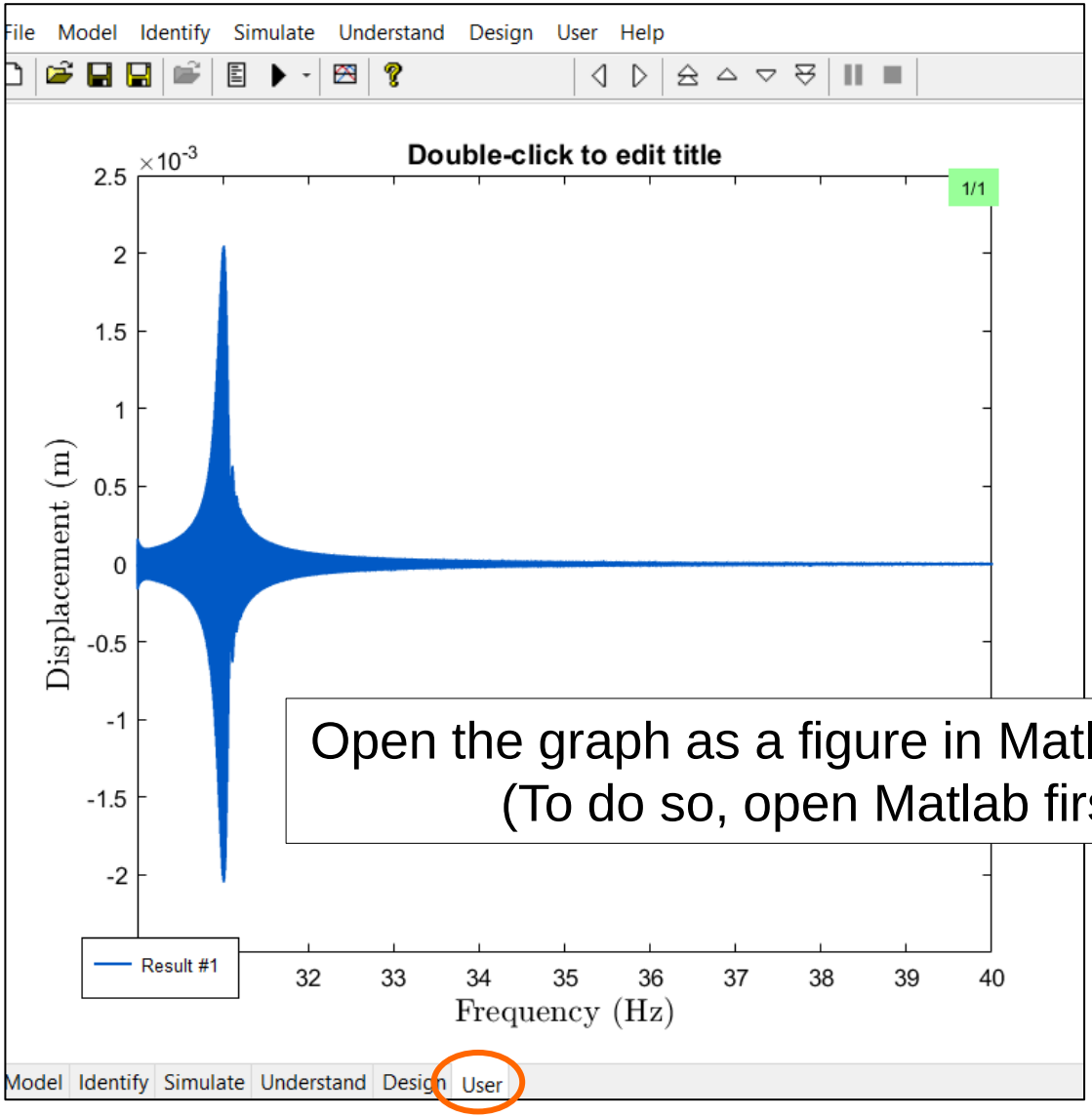
Now: Run


File Model Identify Simulate Understand Design User Help
Displacement vs time, dof n°1
×10-3
1/1
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
x1 (m)
30 31 32 33 34 35 36 37 38 39 40
Frequency (Hz)
= first resonance frequency OK!
Model Identify Simulate Understand Design User

Save Your Results in a Curve Stack



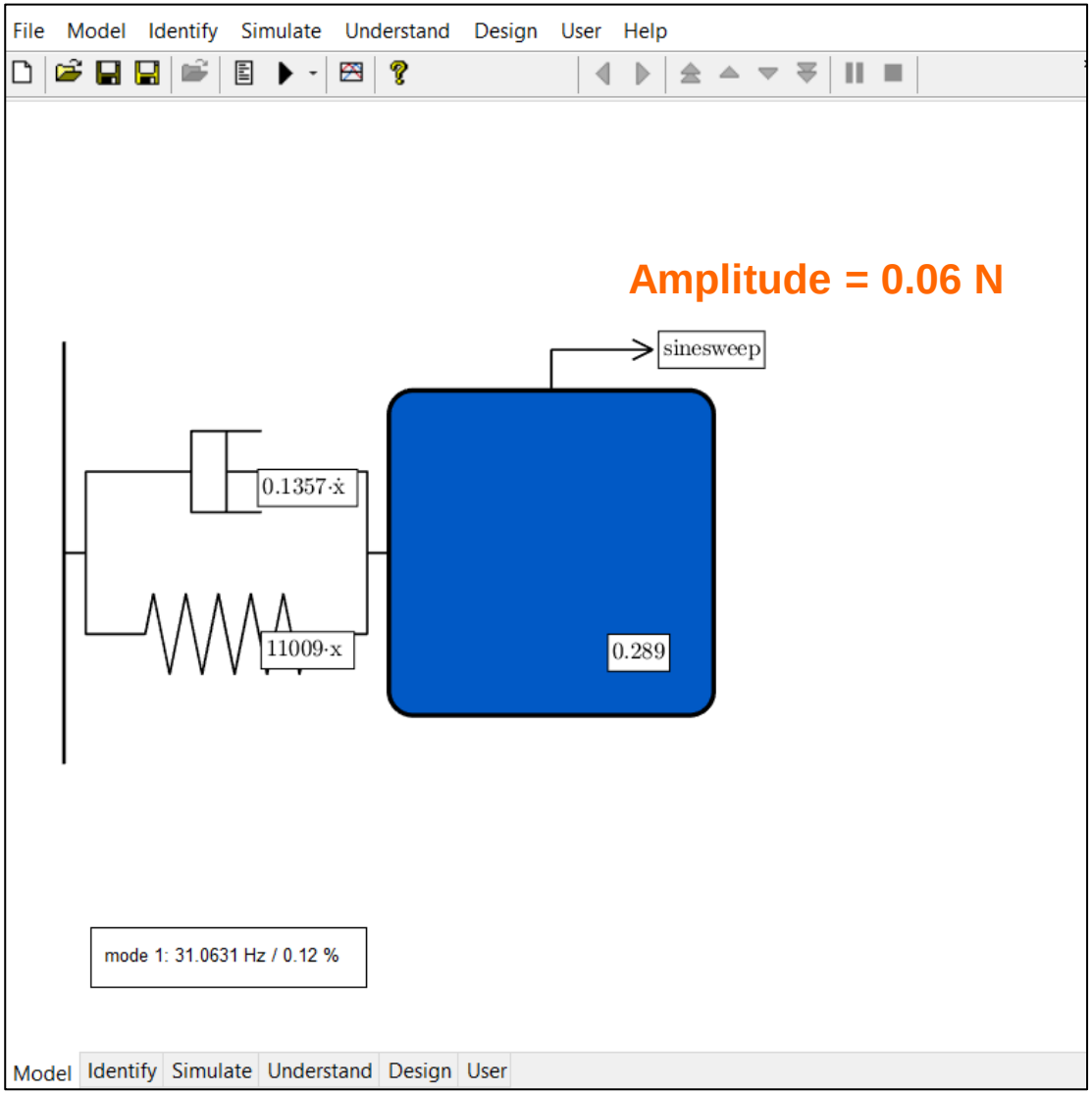
Check Your Results Anytime



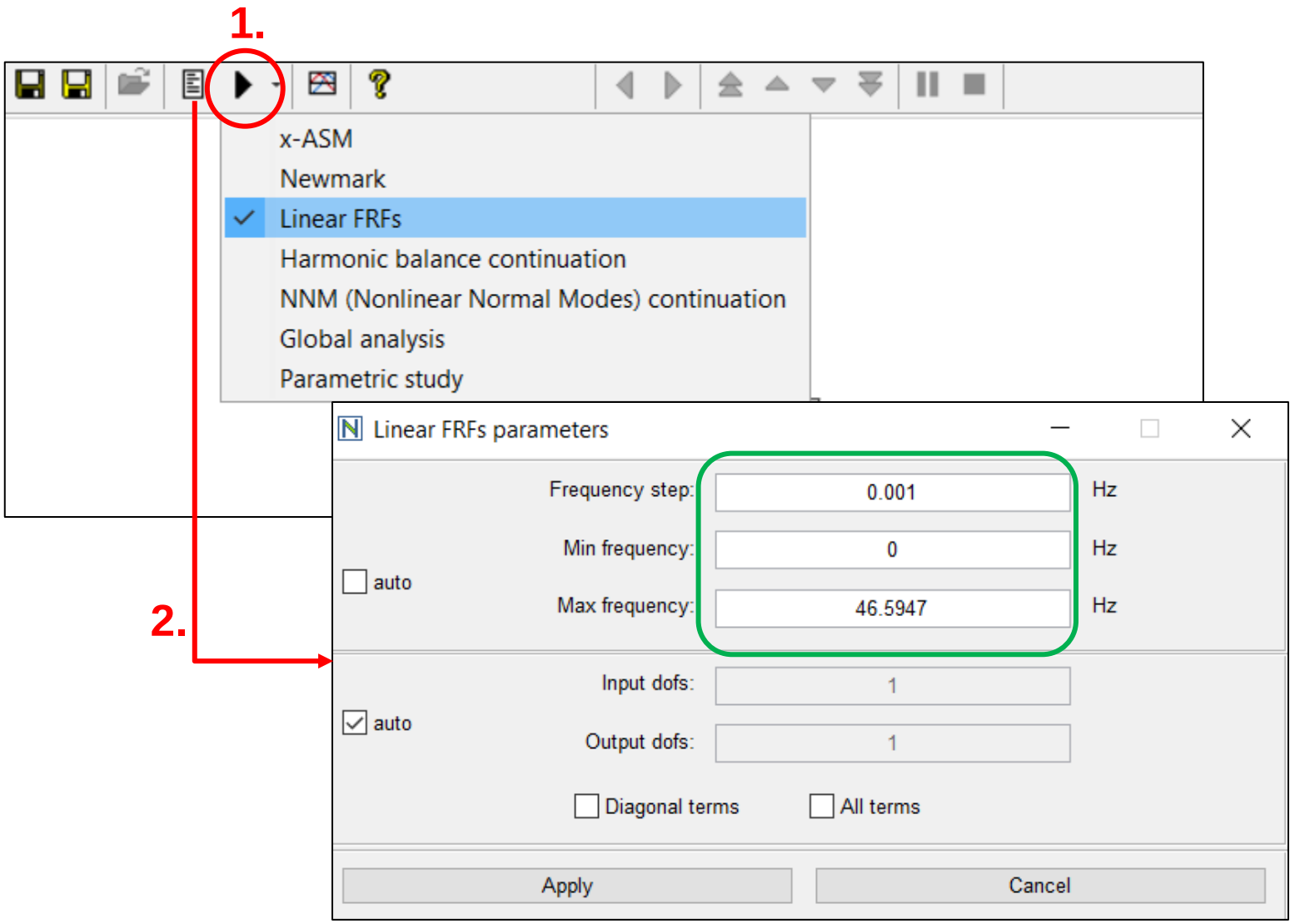
Open the graph as a figure in Matlab with *F4*
(To do so, open Matlab first)

Frequency Response Functions

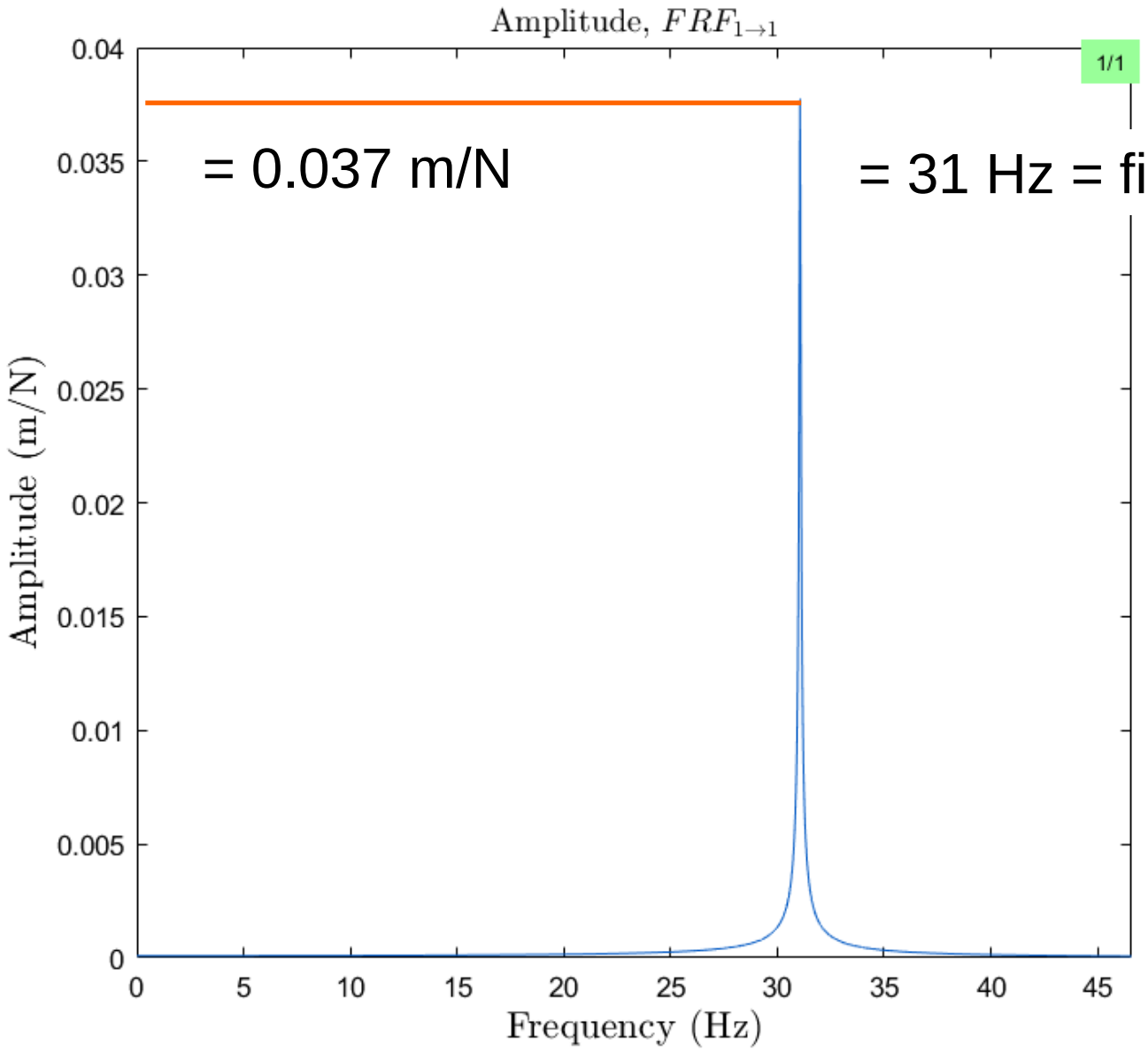
The Linear Model



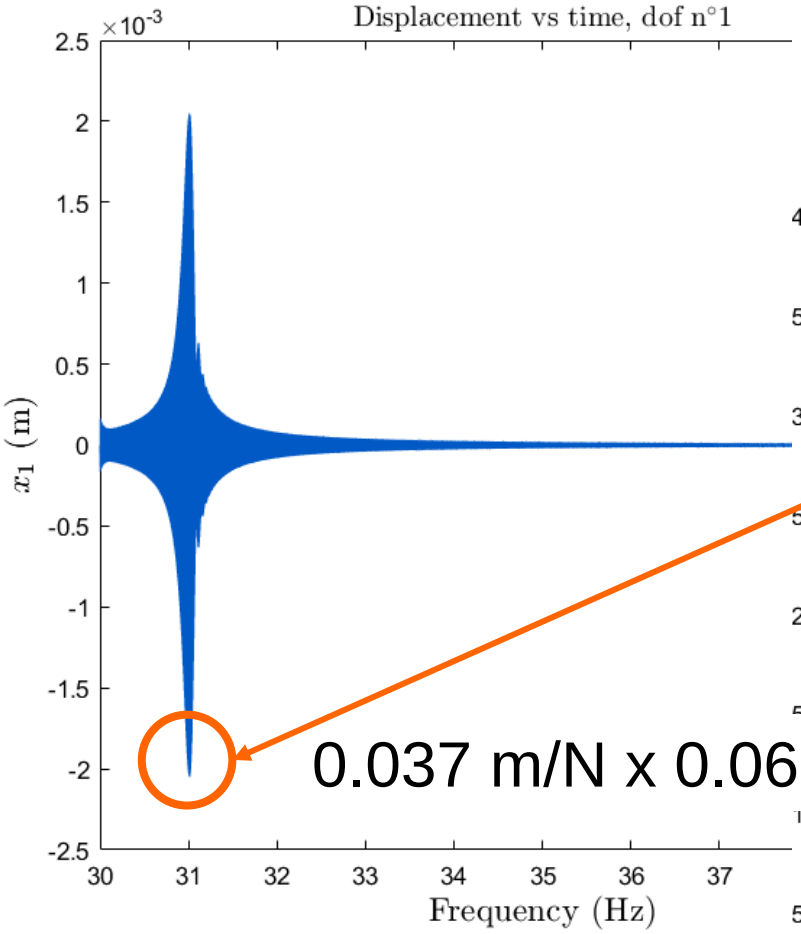
Calculate the Linear FRF …

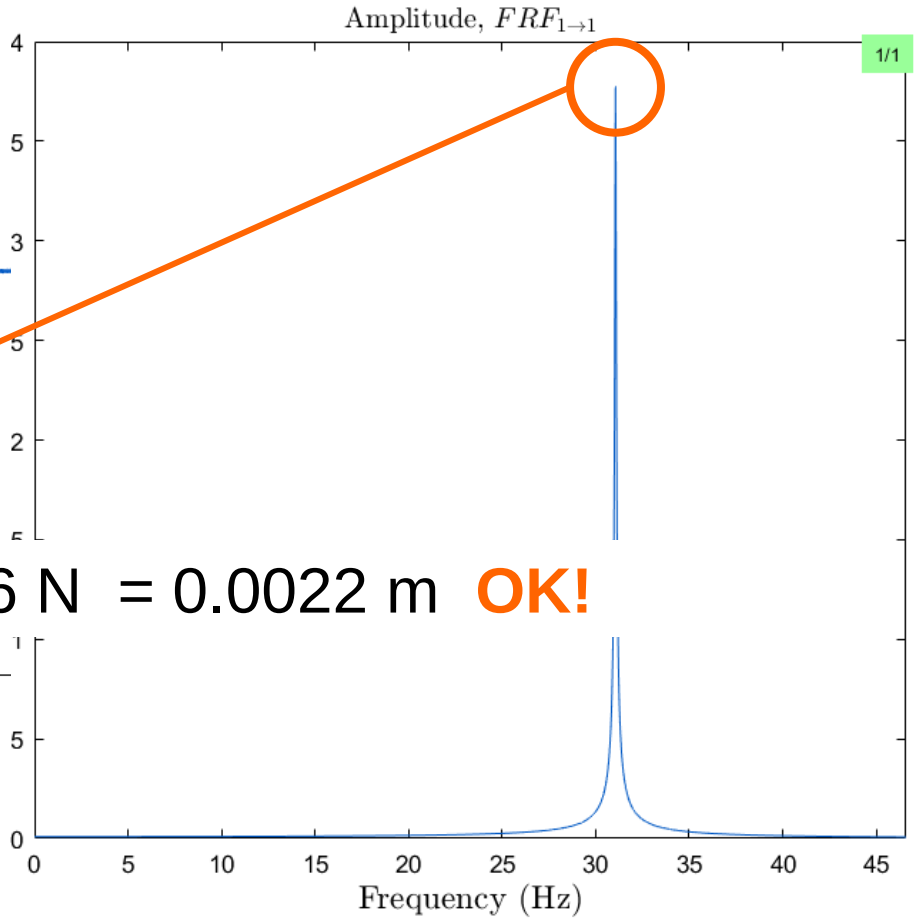


And Check the Result



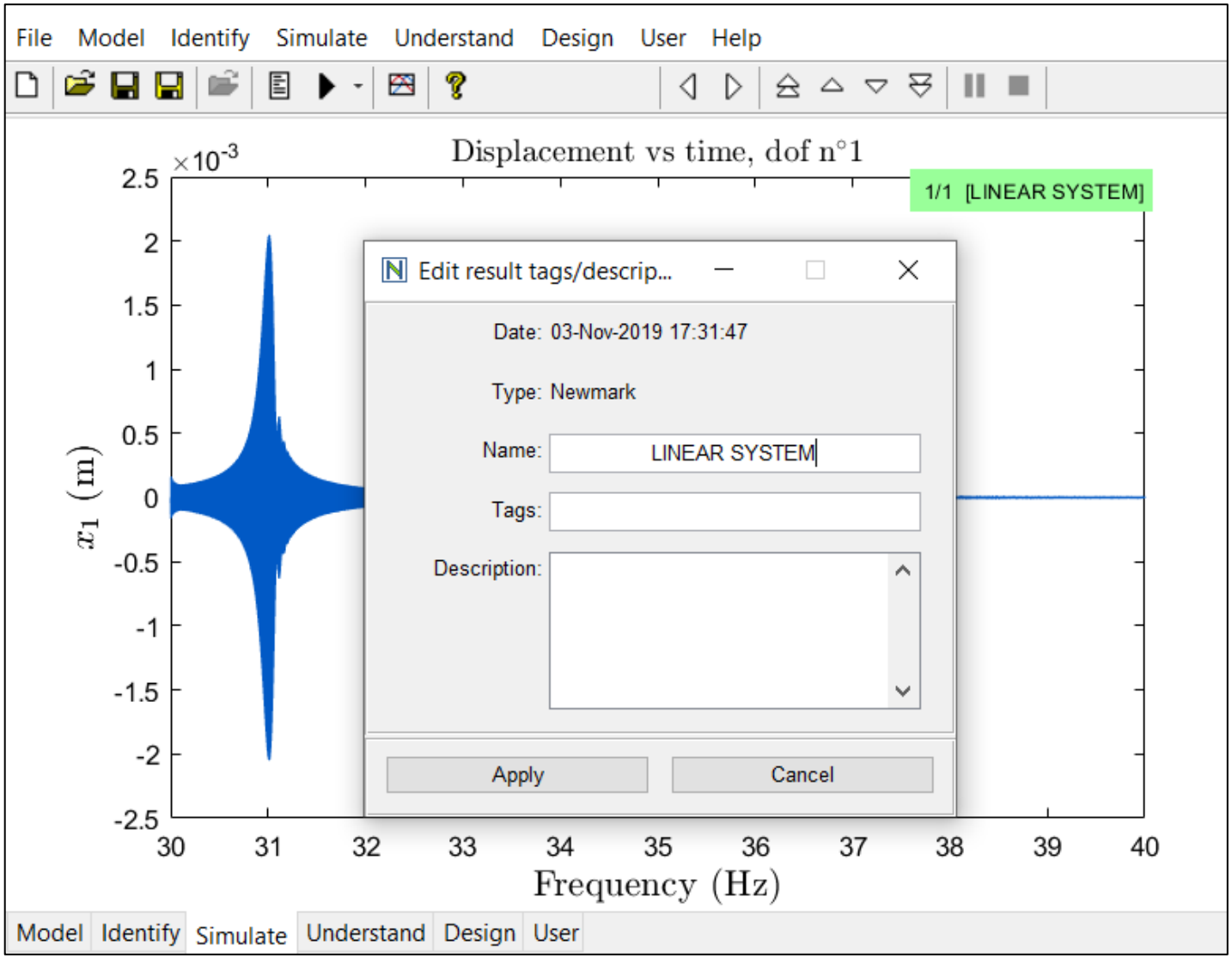
Compare the Time and the Frequency Response



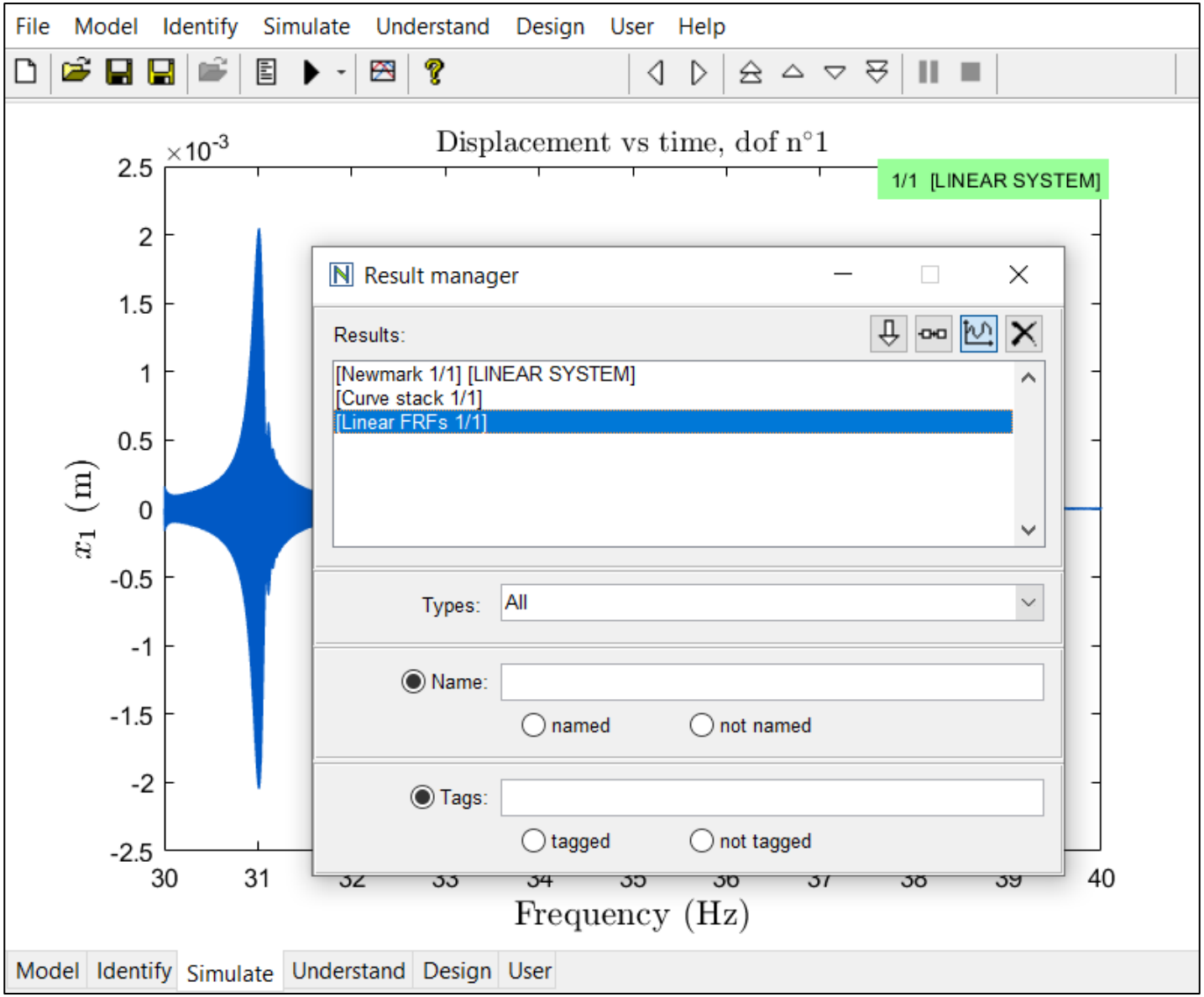


0.037 m/N x 0.06 N = 0.0022 m **OK!**

You Can Tag Your Results (F11) …

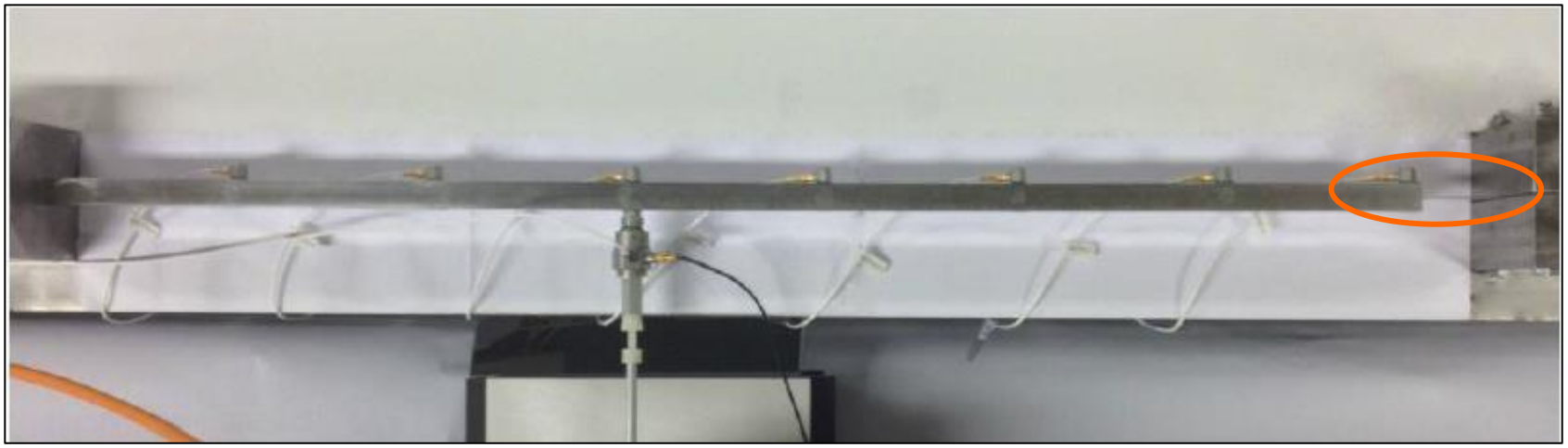


And Manage All Your Results (F12)



Launch Your First Nonlinear Simulation

Nonlinear Model of the 1st Beam Mode

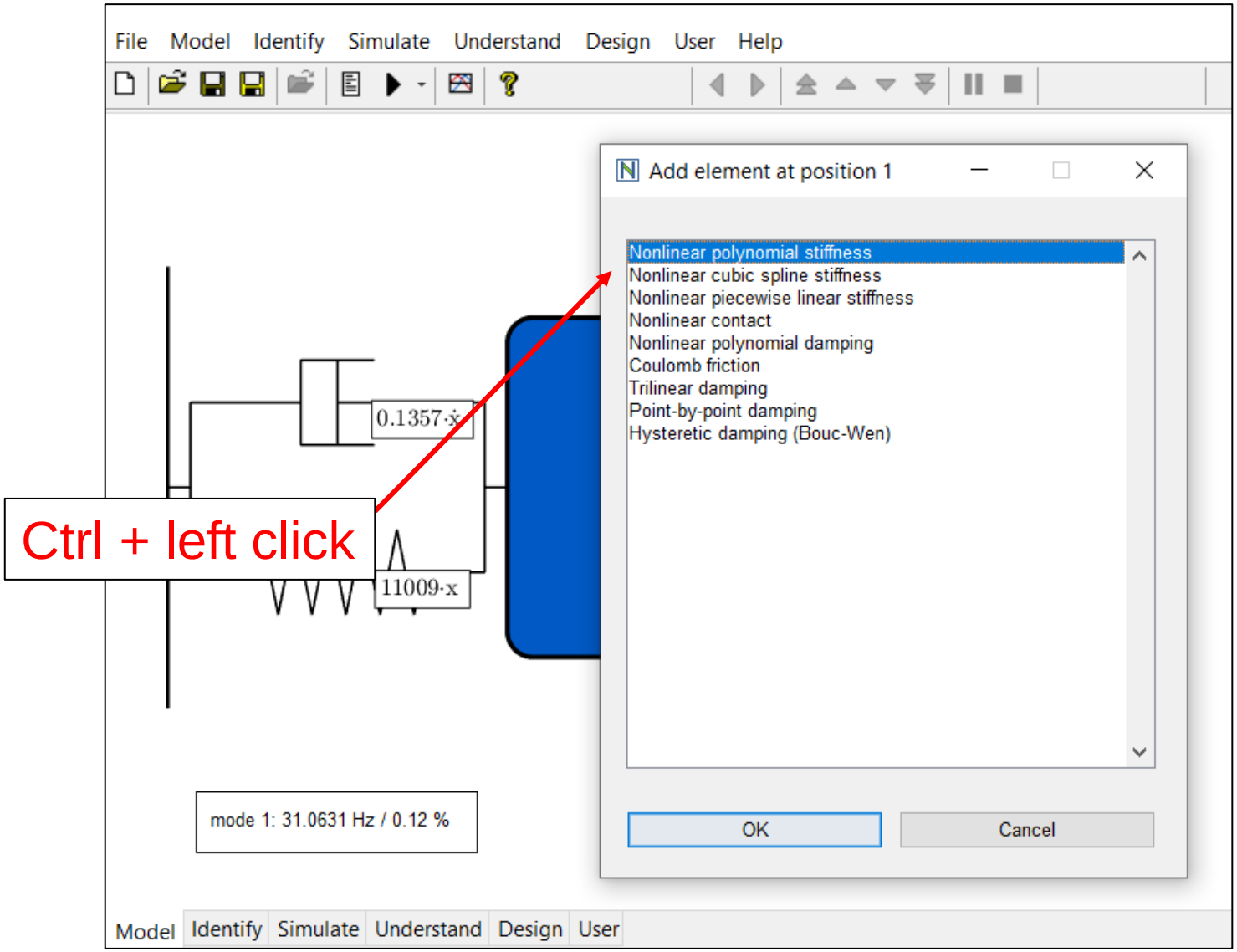


Linear model identified at low level (31 Hz, 0.12%):

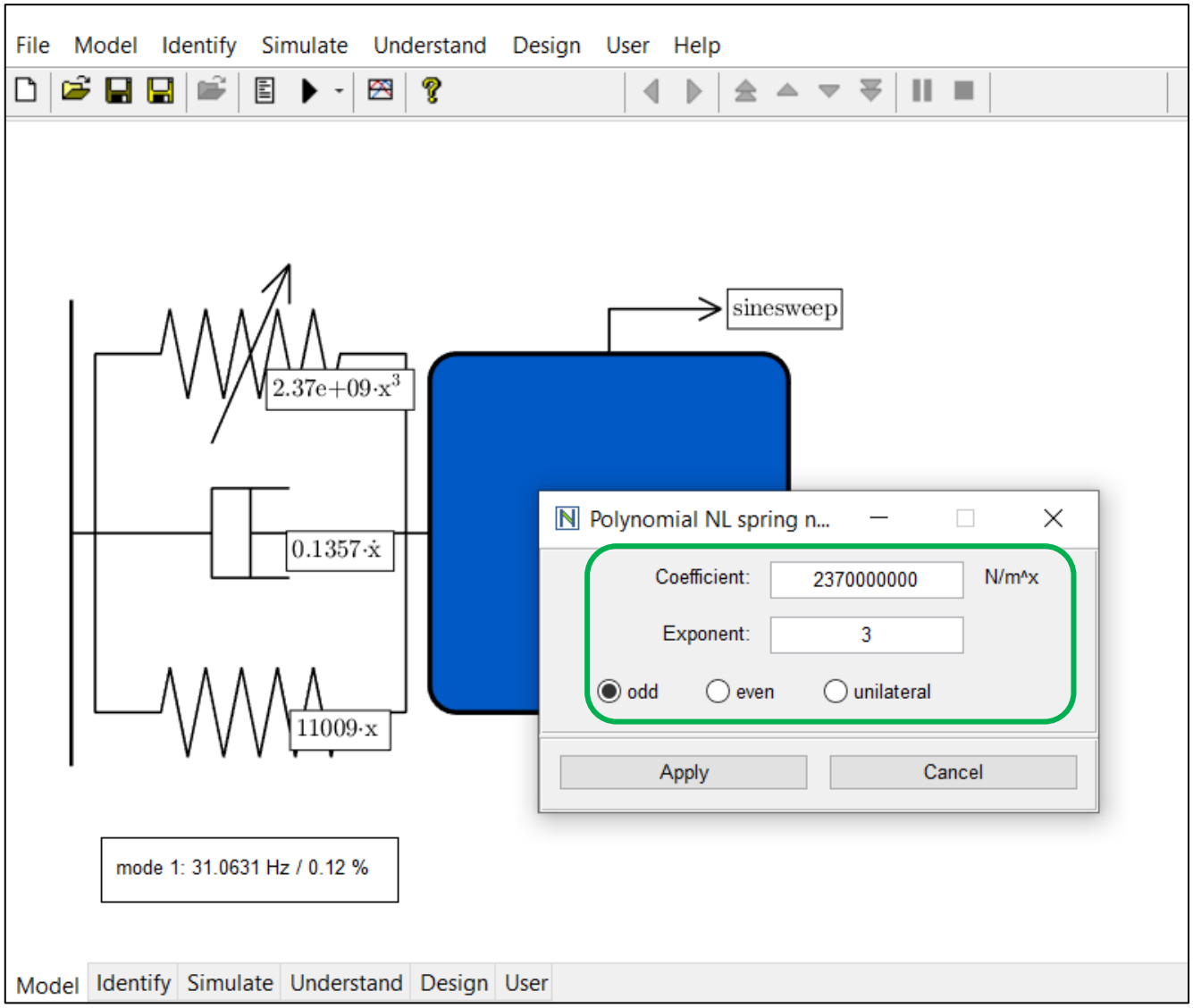
$$0.289\ddot{x} + 0.1357\dot{x} + 11009x = F\sin\omega t$$

Nonlinearity identified at high level: $2.37 \cdot 10^9 x^3$

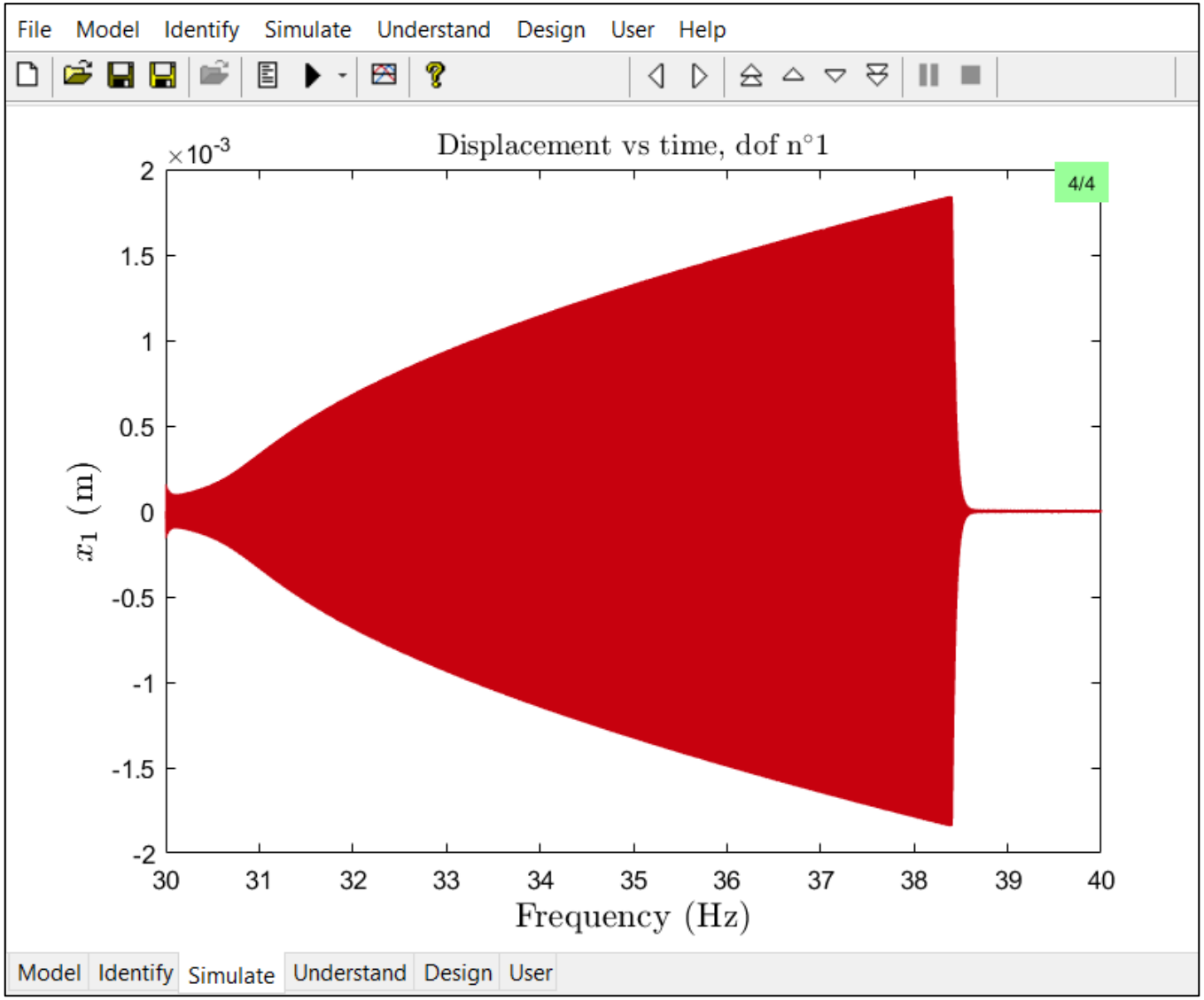
Upgrade the Linear Model from T02 …



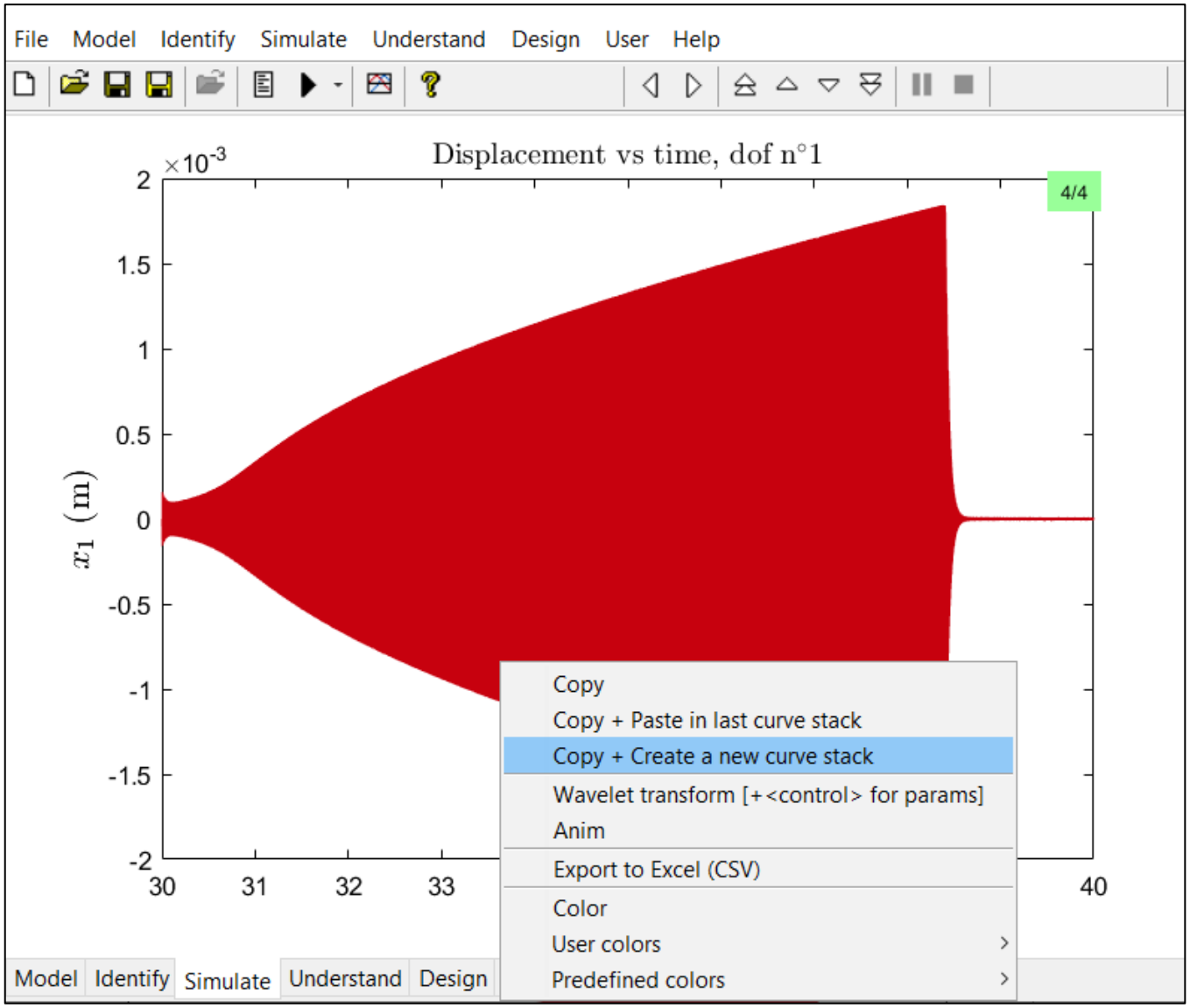
With a Cubic Spring



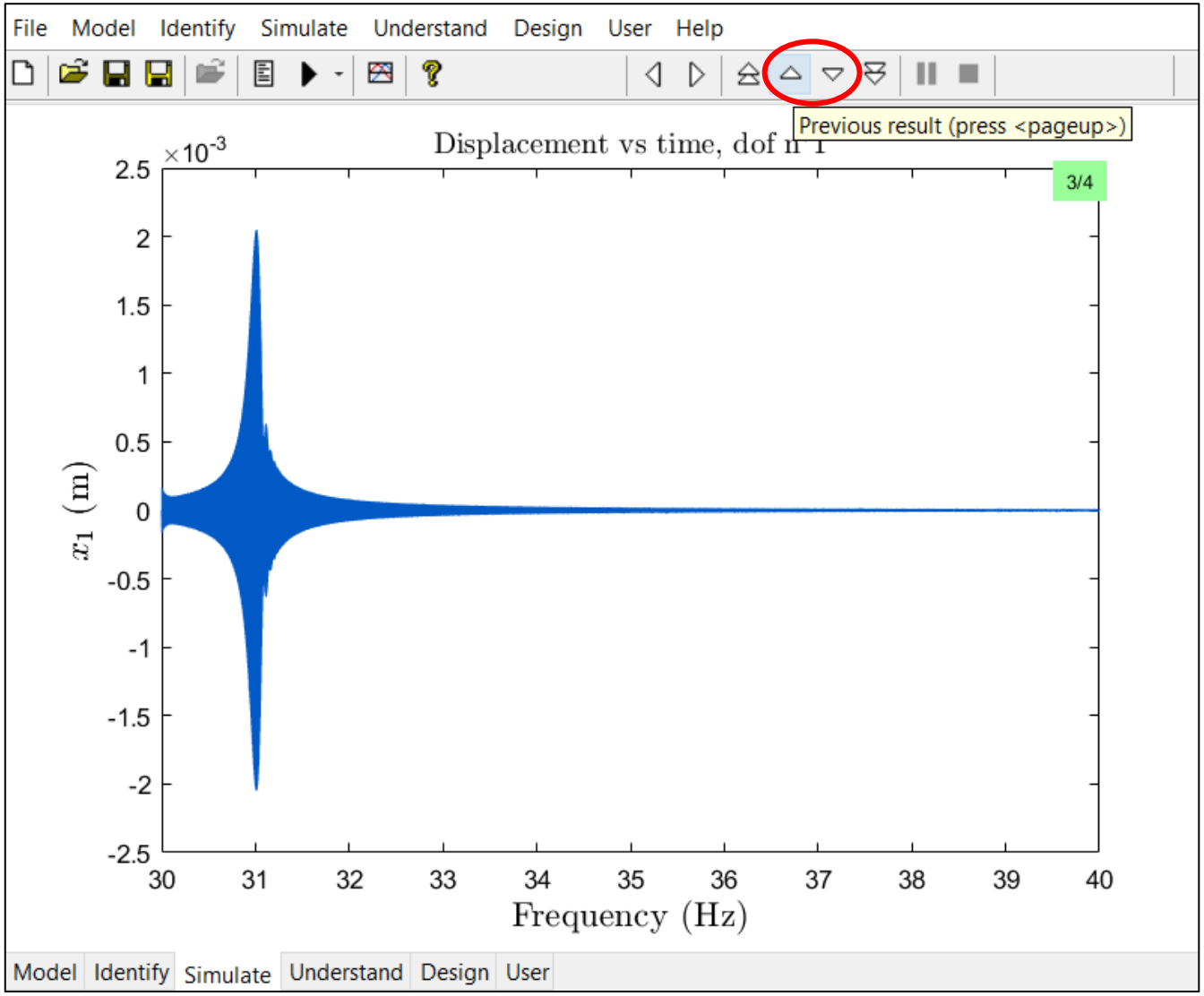
Run the Newmark Time Integration Again …



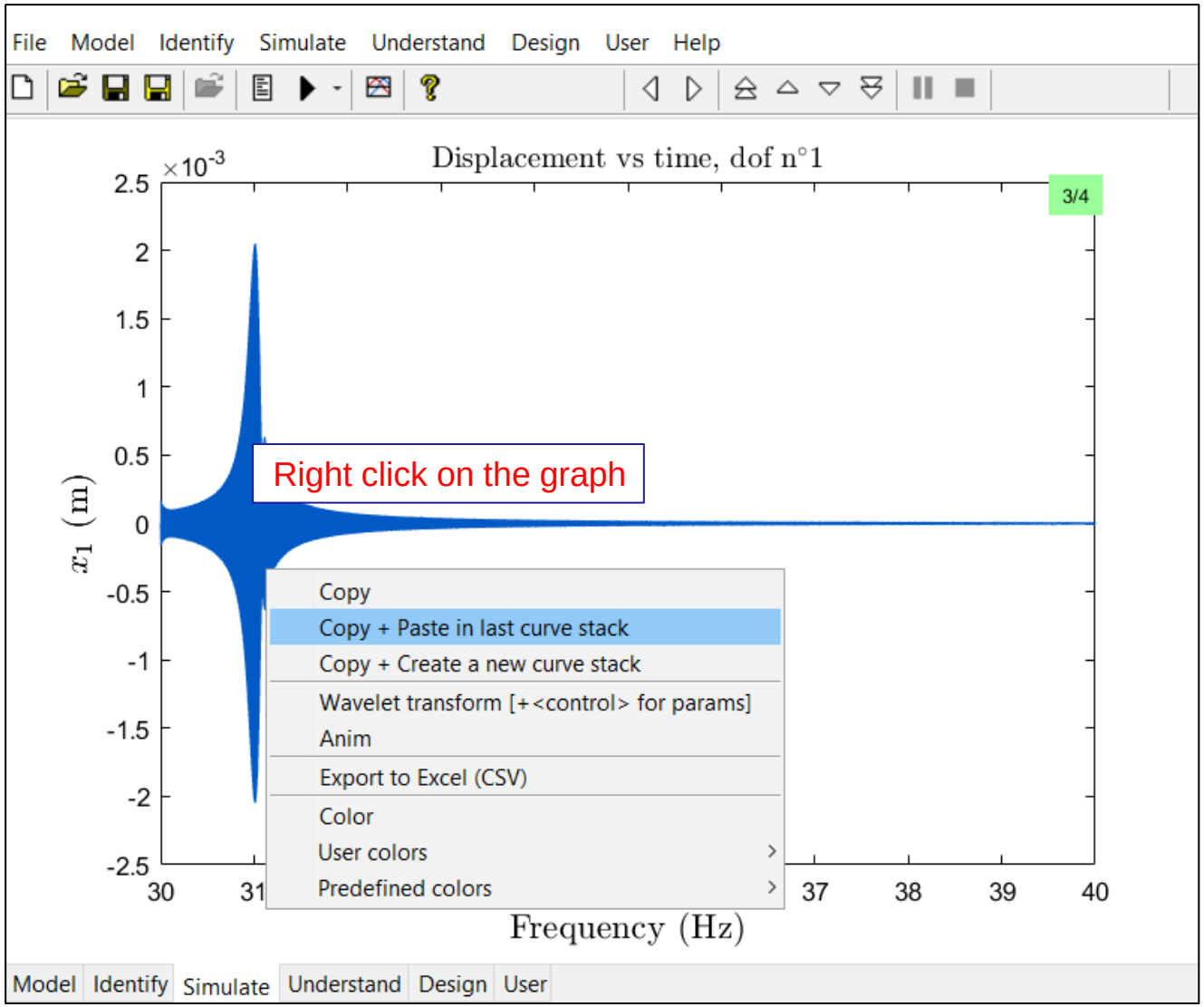
And Save Your Results For Comparison



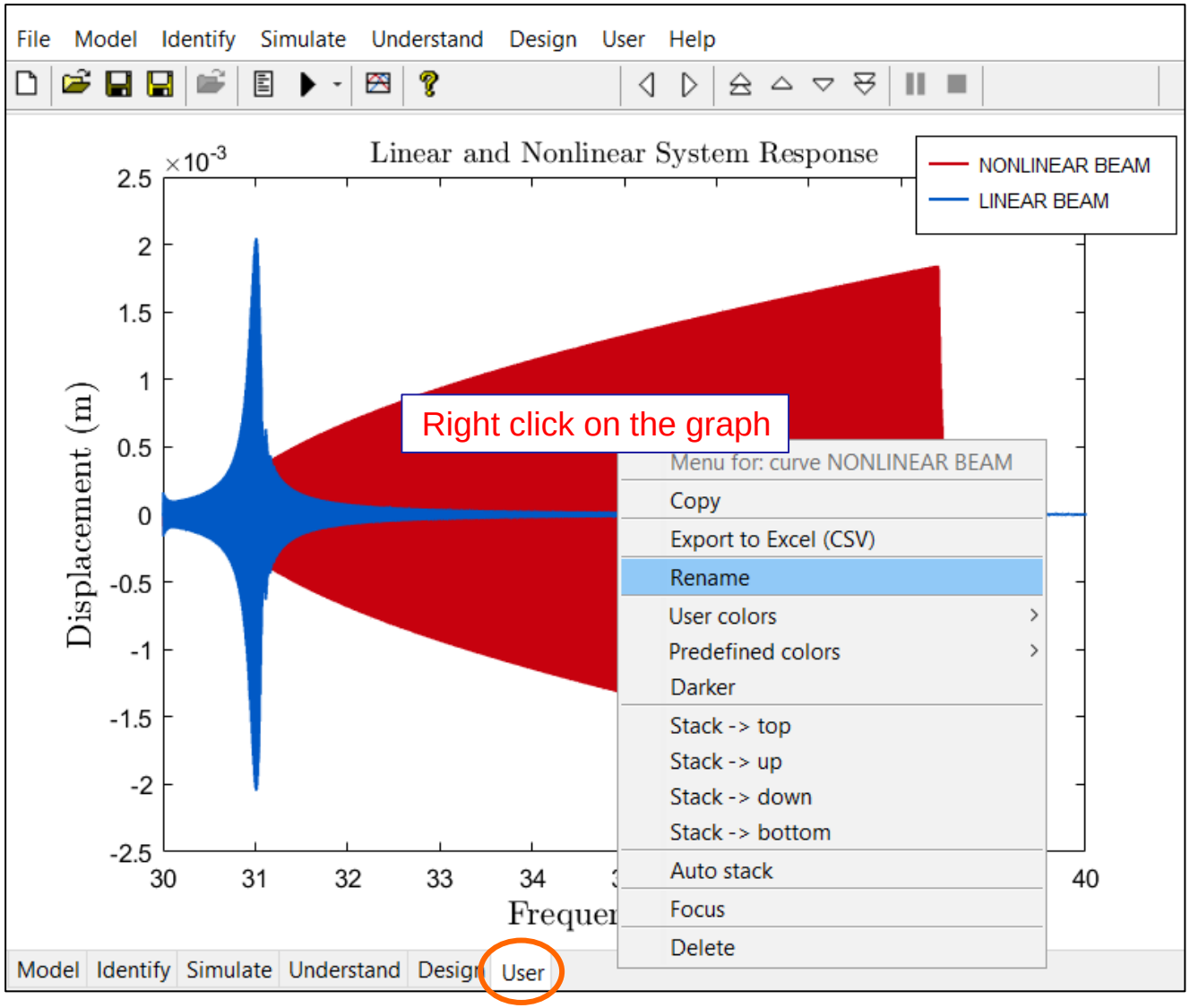
You Can Scroll through Previous Results



And Save Different Results in the Same Curve Stack

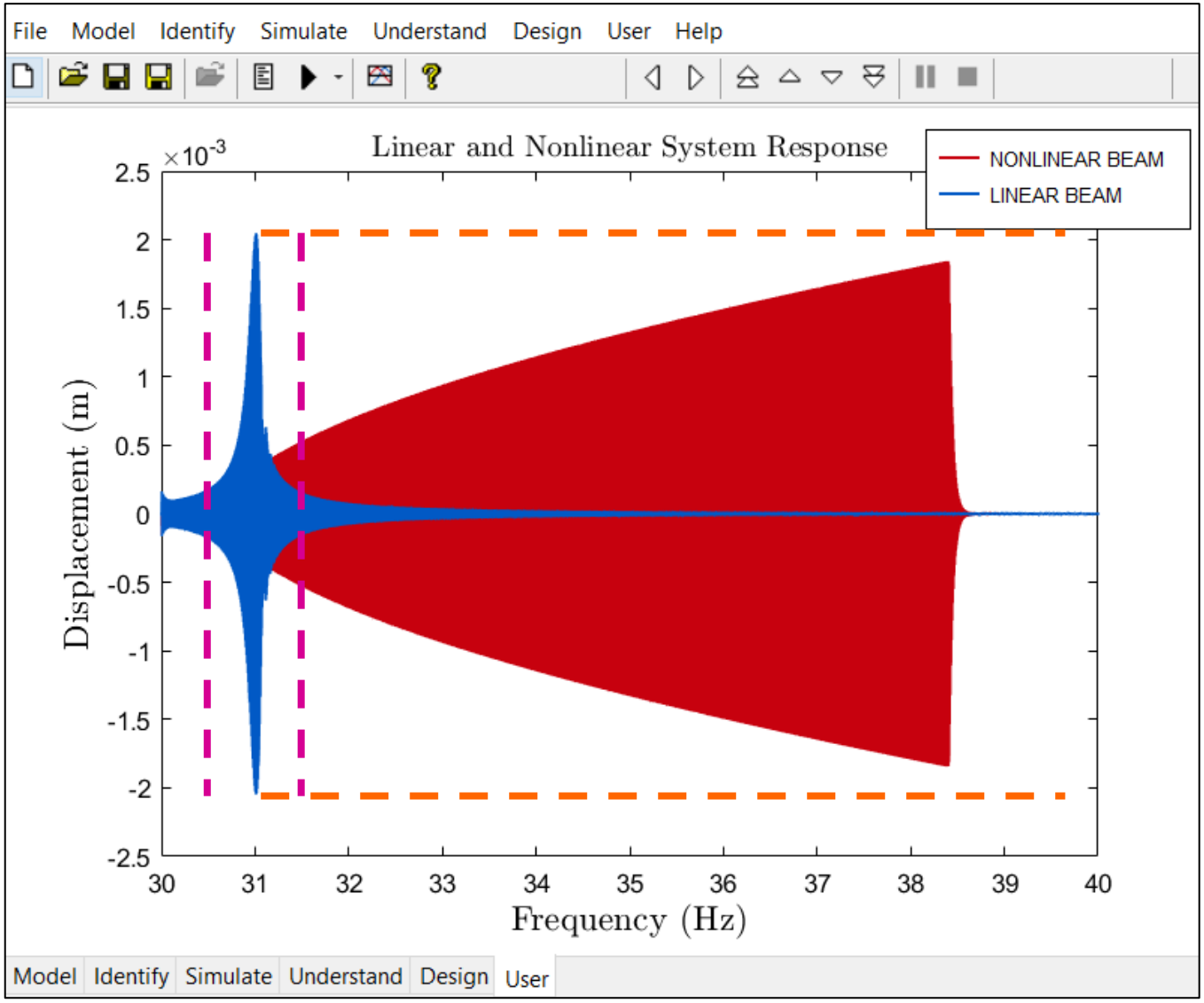


Rename and Arrange Everything in Your Graph …

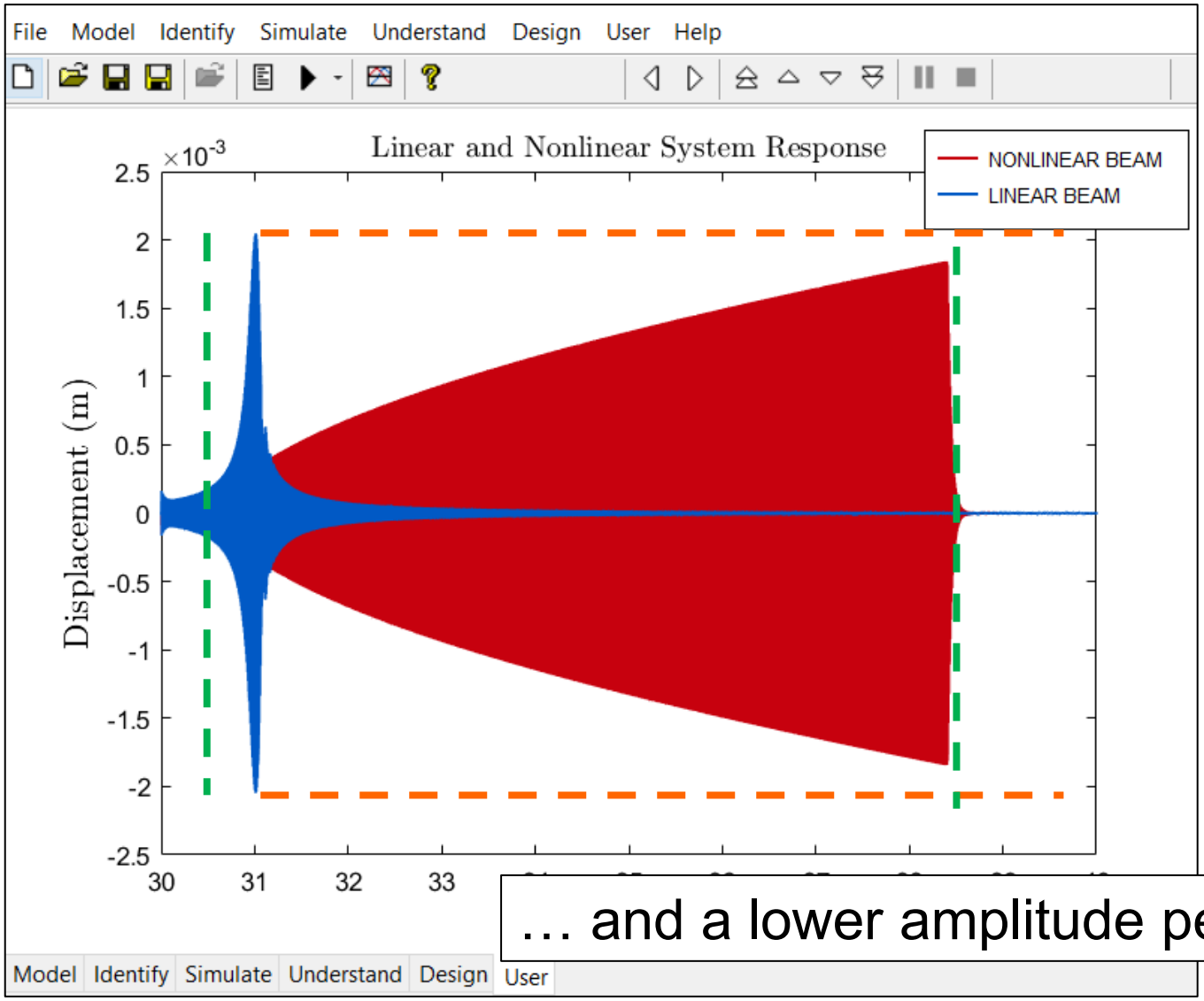


What can we observe?

Nonlinearity Introduces a Fundamental Change

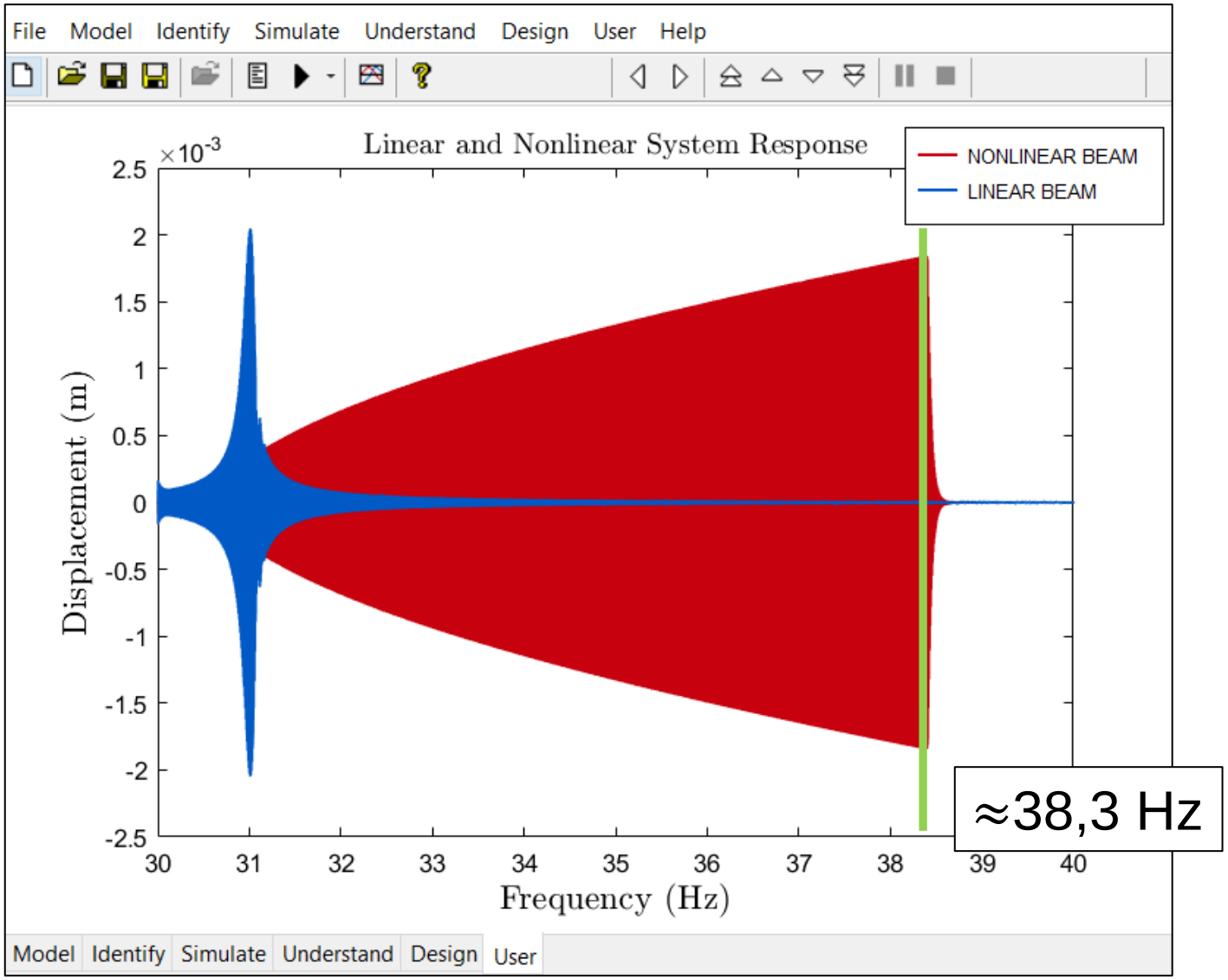


The Nonlinear System Response Has a Greater Bandwidth …



… and a lower amplitude peak

The Resonance Frequency Shifts



A Jump Downwards Can Be Observed