Nonlinear Vibrations of Aerospace Structures

Tutorial 01: Introduction to NI2D



T01 Nonlinear Vibrations Course at ULiège

Free access to the NI2D software commercialized by the NOLISYS company.

Stand alone .exe.





A prototype of the structure is available:

 \rightarrow Test it, identify the nonlinearities and upgrade the linear FEM.

A priori knowledge about the nonlinearities is available:

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

Launch NI2D and activate your license under Preferences.

File Model Identify Simulate Understa	nd Design User Help
NI2D Preferences	
Default user folder:	E:\
User email address:	
License file:	E:\NI2D\gaetan2024.lic
Favourite FE software:	none Nastran Samcef
FE software binaries PATH:	
FE analysis folder:	
Open last model on startup	Use busy indicator Auto-save
Help Default u	nits Apply Cancel

Create a new model

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	NI2D:	New m	iodel	ustem	MCK matric	oc Eini	to clom	ont mo	dal D	40 mod	-	-	X		
	Existing		Lumped model	l	FE Model (.mat) Linear da	sses: Mass: mping: ffness:	FE		0.1 1	easure Data (.uff)		Kg N.s/r N/m	Measured Data (.mat)		
			Contin	ue >						Ab	ort				





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	NI2D help	-	You find	the software
	mouse-wheel control+mouse-whe	Zoom in/out on 3D graphics (forward=zoom in, backward=zo Zoom in/out on 2D graphics (forward=zoom in, backward=zo	docume	entation here
	mouse-right	Menus on tab background and model elements		
	control+mouse-left	Add element between masses		
	shift+mouse-left	Enable/disable elements		
	alt+mouse-left	Select/unselect masses		
	double+mouse-left	Edit element or mass		
	f2	Send graphic to Windows clipboard		
	f3	Send graphic to image file (automatic choice)		
	f4	Clone current NI2D window		
	f5	Run selected solver		
	f6	Change parameters of selected solver		
_	. f7	Add to report (automatic choice)		
	f8	Add to report (editing title/comments)		
	f12	Result manager		
	escape	Reset window		
	tab	Last two results displayed		
	2	Update window		
	%	NI2D command prompt		
	control+c	Copy curve in NI2D clipboard		
	r	Reset 2D zoom		
	0	Reset initial conditions		
	U	User colors for selected masses		
The help menu is ad	apted to	each tab		
	control+v	Select and paste settings (model, views, parameters)		
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Launch Your First Numerical Simulation

Let's reproduce the result of the previous lecture







m=k=1, c=F(t)=0

Create a new model: 1 DOF linear oscillator

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	NI2D [N	lew model]					×	
	User models	Spring/mass system	MCK matrices Finit	te element model	DAQ model	Measured signals		
			Number of masses:	1				
		2	Mass:	1		kg		
		Z	Stiffness:	1		N/m		
			Damping:	0		N.s/m		
			Ground fixations:	✓ first mass	last mass			
			Model units:	m,kg,N				
				3				
	Н	elp	Preferences	Continue		Exit		

You can change the coefficients anytime ...



Double click on the element to change the coefficients

Calculate the time response with Newmark

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	x-ASM				
	 Newmark 				
	Linear FRFs				
	Harmonic bala	nce contin	uation		
	NNM (Nonline	ar Normal	Modes)	continuat	ion
	Global analysis	;			
	Parametric stud	dy			

Crucial to choose the right sampling frequency

					acy
			Stability limit	Amplitude error	Periodicity error
Algorithm	γ	β	ωh	ho -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	$\frac{1}{2}$	$\frac{1}{4}$	œ	0	$\frac{\omega^2 h^2}{12}$
Average constant acceleration (modified)	$\frac{1}{2} + \alpha$	$\frac{(1+\alpha)^2}{4}$	8	$\alpha - \frac{\omega^2 h^2}{2}$	$\frac{\omega^2 h^2}{12}$

Average constant acceleration	$\frac{1}{2}$	$\frac{1}{4}$	œ	0	$\frac{\omega^2 h^2}{12}$
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Error for 20 points per period:

$$\frac{\omega^2 h^2}{12} = \frac{\left(\frac{2\pi}{T}\right)^2 \left(\frac{T}{20}\right)^2}{12} = \frac{39.4}{400.12} = 0.0082 = 0.82\%$$

Error for 100 points per period:

$$\frac{\omega^2 h^2}{12} = \frac{\left(\frac{2\pi}{T}\right)^2 \left(\frac{T}{100}\right)^2}{12} \approx \frac{39.4}{10000.12} = 0.0003 = 0.03\%$$

Select an appropriate time step and the final time

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	Newmark parameters				
	Sampling frequency:	1000	Hz	_	0.01 sec
	adapt Time step:	0.001	sec	2	(628 points
	Time steps per period:]		per period)
					per peried)
	Initial time:	0	sec	3	
	Duration:	10	sec —		20 sec
	Number of time steps:	10000			
	Number of periods:]		
	2				
	Saved dots:				
		disp. only verall m	notion		
	Memory:	◯ low 4 normal ◯	auto		
	Advanced Initial cond.	Apply Run (F5)	Cancel		

Specify initial conditions

Newmark parameters

San	npling frequency:	1000	Hz
adapt	Time step:	0.001	sec
Times	steps per period:		
	Initial time:	0	sec
	Duration:	10	sec
Numb	er of time steps:	10000	
Nu	mber of periods:		
	Saved dofs:	all selected	
		disp. only verall me	otion
	Memory:	◯ low	auto
Advanced	Initial cond.	Apply Run (F5)	Cancel
	1		

Initial conditions

Degree of freedom	all	∼ →O	2	
Displacement:		1		m
Velocity:		0		m/sec
Apply		C	ance	1

Run the simulation



Progress window: useful for long simulations but slows down simple simulations

Type 'W' in the model tab to remove it

Send the result to the user tab

Right click on the curve

Specify different initial conditions

Run the simulation

Send the result to the user tab

Right click on the curve

Compare the curves

Select an inadequate time step

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	Newmark parameters				
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	Time steps per period:]		per period)
			1		1 1 /
	Initial time:	0	sec		
	Duration:	10	sec		
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		disp. only verall m	otion		
	Memory:	⊖low 3 [®] normal ⊖	auto		
	Advanced Initial cond.	Apply Run (F5)	Cancel	-	

Send the result to the user tab

Right click on the curve

Compare the time series

And zoom (Type "r" to dezoom)

Launch your first nonlinear simulation

Introduce a cubic spring in the model (coefficient=1)

Ctrl+left click between the wall and the mass

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	Add element at position 1 Linear damping Nonlinear polynomial stiffness Nonlinear cubic spline stiffness Nonlinear polynomial damping Coulomb friction Trilinear damping Point-by-point damping Hysteretic damping (Bouc-Wen) Volume	mode 1: 0.15915 Hz

Color: red, ICdisp=1 and time step=0.01s

You see the hardening effect of the cubic spring

Send the result to the user tab

Represent the acceleration signal

Right click next to the vertical axis

Type a or z to switch between displacement and acceleration

We clearly see the harmonics

Reconstruct the backbone curve by simulating the system with cubic nonlinearioty for different initial conditions

Simulate a cubic spring with a negative coefficient and compare with the linear oscillator.

Simulate a Helmotz oscillator.

