

NONLINEAR EFFECT ON MODAL DATA ANALYSIS METHOD

Lucas G. Horta  
NASA Langley Research Center  
Hampton, Virginia

## NONLINEAR EFFECT ON MODAL DATA ANALYSIS METHODS

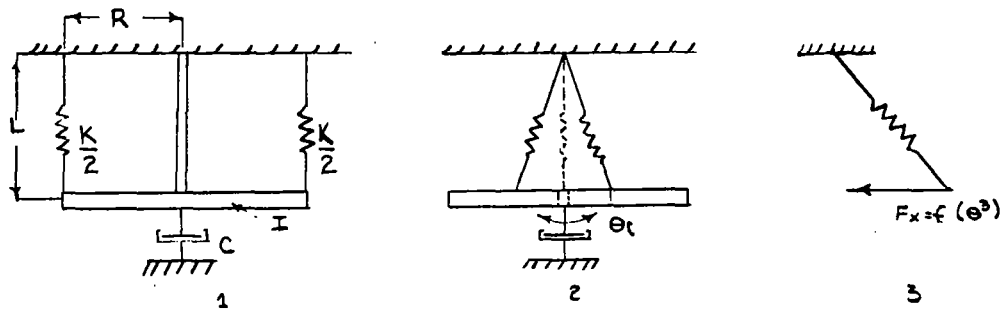
### OBJECTIVES:

- 1 - DETERMINE HOW THE PRESENCE OF NONLINEARITIES IN STRUCTURAL TEST DATA CAN BE DETECTED WHEN USING MODERN LINEAR MODAL DATA ANALYSIS METHODS.
- 2 - EVALUATE THE EXTENT TO WHICH LINEAR ALGORITHMS CAN PROVIDE USEFUL INFORMATION ON NONLINEAR SYSTEMS.

### APPROACH:

- 1 - GENERATE SIMULATED TEST DATA BY A NONLINEAR ANALYTICAL MODEL.
- 2 - USE LINEAR METHODS (IBRAHIM TIME DOMAIN ALGORITHM (ITD) AND FREQUENCY-DOMAIN TRANSFER FUNCTION TECHNIQUES) TO ANALYZE SETS OF THIS DATA WITH CONTROLLED PARAMETRIC VARIATION.

### SINGLE DEGREE OF FREEDOM MODEL



SYSTEM DIFFERENTIAL EQUATION FOR SMALL DISPLACEMENT

$$\frac{d^2\theta}{dt^2} = -\frac{1}{2} \frac{KR^4}{L^2I} \theta^3 - \frac{JG}{LI} \theta - \frac{C}{I} \frac{d\theta}{dt}$$

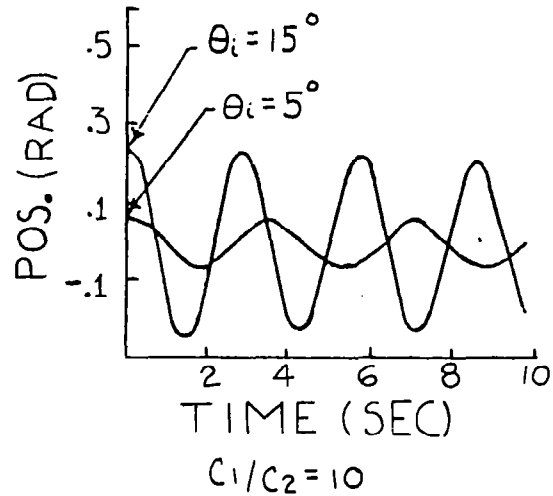
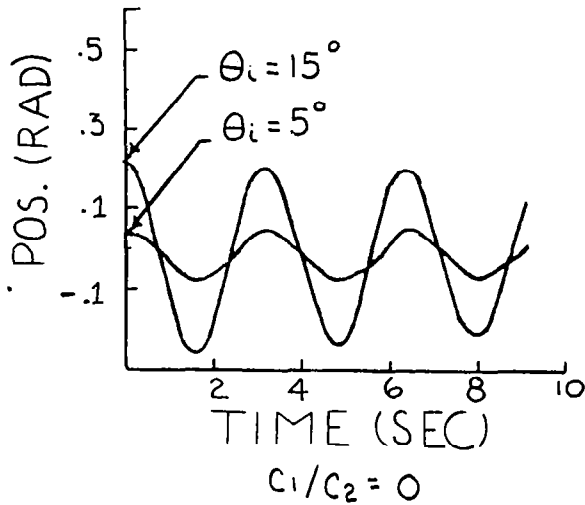
GENERAL FORM

$$\ddot{\theta} = C_1 \theta^3 + C_2 \theta + C_3 \dot{\theta}$$

LINEAR NATURAL FREQUENCY = 0.288 HZ

LINEAR MODAL DAMPING = 0.01

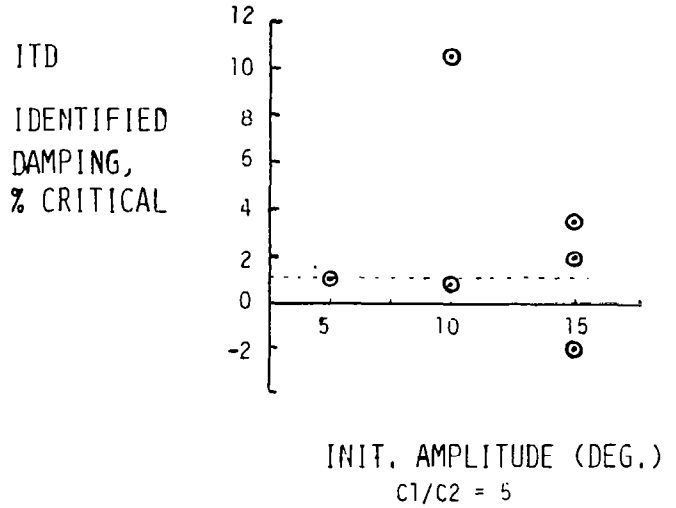
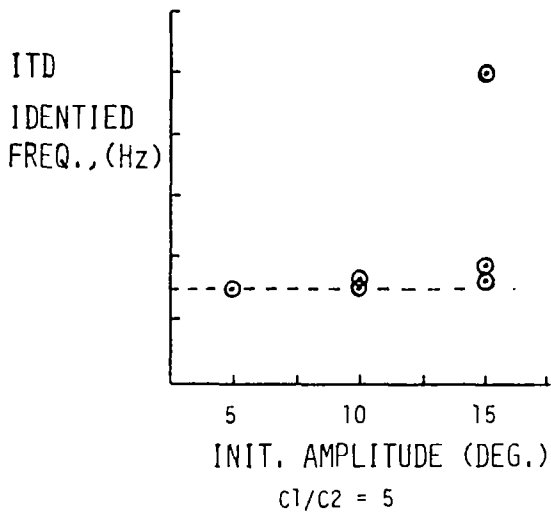
## SINGLE DEGREE OF FREEDOM RESPONSE



## THE IBRAHIM-TIME-DOMAIN (ITD) MODAL DATA ANALYSIS METHOD

- 0 AN OFF-LINE LARGE-SCALE DATA ANALYSIS METHOD DEVELOPED FOR STRUCTURAL DYNAMICS TESTS.
- 0 OPERATES ON FREE-DECAY RESPONSES SOLVING MANY DATA CHANNELS SIMULTANEOUSLY.
- 0 HAS PROVEN MORE SUCCESSFUL THAN OTHER LABORATORY METHODS FOR HANDLING NOISE, LARGE SYSTEMS, AND CLOSELY SPACED MODES.

# SINGLE DEGREE OF FREEDOM RESULTS

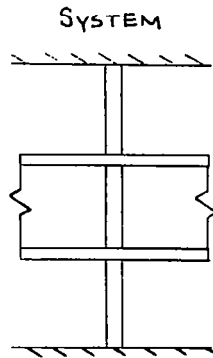


## SINGLE DEGREE OF FREEDOM RESULTS COMPARISON

	$F_1$ (Hz)	$F_2$ (Hz)	$F_3$ (Hz)
ANALYTICAL	0.3042	0.9127	1.52
ITD	0.3030	0.8970	1.562
% DIFFERENCE	0.39	1.72	2.76

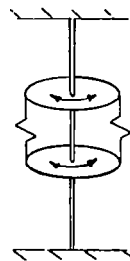
$$C1/C2 = 5 \quad IC = 10^\circ$$

## TWO DEGREE OF FREEDOM ANALYTICAL MODEL

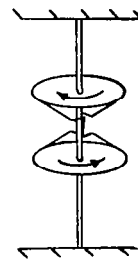


### EQUATION OF MOTION

$$\begin{bmatrix} I_1 & 0 \\ 0 & I_2 \end{bmatrix} \begin{Bmatrix} \ddot{\theta}_1 \\ \ddot{\theta}_2 \end{Bmatrix} + \begin{bmatrix} C_{11} & -C_{12} \\ -C_{21} & C_{22} \end{bmatrix} \begin{Bmatrix} \dot{\theta}_1 \\ \dot{\theta}_2 \end{Bmatrix} + \begin{bmatrix} K_{11} & -K_{12} \\ -K_{21} & K_{22} \end{bmatrix} \begin{Bmatrix} \theta_1 \\ \theta_2 \end{Bmatrix} + \begin{bmatrix} E & 0 \\ 0 & -E \end{bmatrix} \begin{Bmatrix} (\theta_1 - \theta_2)^3 \\ (\theta_1 - \theta_2)^3 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix}$$

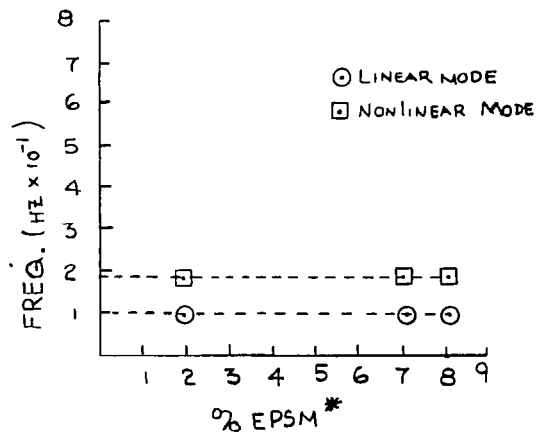


LINEAR Mode  
 $F_1 = .100 \text{ Hz}$

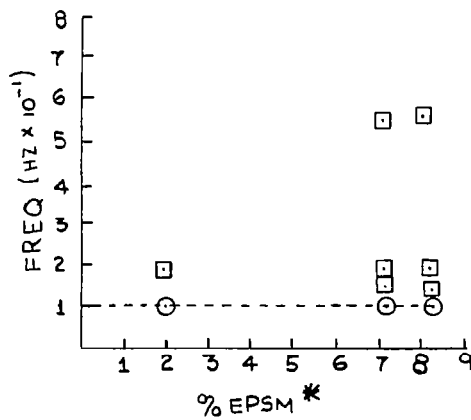


NON LINEAR Mode  
 $F_2 = .199 \text{ Hz}$

## TWO DEGREE OF FREEDOM RESULTS



ASSUMED DOF = 6



ASSUMED DOF = 10

\* EPSM = ENERGY PROVIDED TO SECOND MODE

## SUMMARY

- 1 - THE ITD MODAL DATA ANALYSIS METHOD SUCCESSFULLY IDENTIFIED THE FREQUENCY COMPONENTS (BUT NOT DAMPING) OF THE TRUE SOLUTION OF A NONLINEAR SYSTEM FROM SIMULATED TEST DATA.
- 2 - THE APPROXIMATE MODAL PARAMETERS OF THE LINEAR SYSTEM CAN BE IDENTIFIED BY THE ITD METHOD WHEN LOW LEVELS OF NONLINEARITIES ARE PRESENT.
- 3 - THE ITD METHOD SUCCESSFULLY IDENTIFIED THE MODAL PARAMETERS OF A LINEAR MODE IN THE PRESENCE OF A NONLINEAR RESPONSE.

## FUTURE RESEARCH THRUST

- 1 - EXPERIMENTAL EVALUATION OF ITD METHOD ON A TWO-DEGREE-OF-FREEDOM NONLINEAR LABORATORY MODEL.
- 2 - APPLICATION OF FREQUENCY-DOMAIN TRANSFER-FUNCTION TECHNIQUES TO THE SAME ANALYTICAL AND EXPERIMENTAL DATA.