# NONLINEAR EFFECT ON MODAL DATA ANALYSIS METHOD

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## 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.

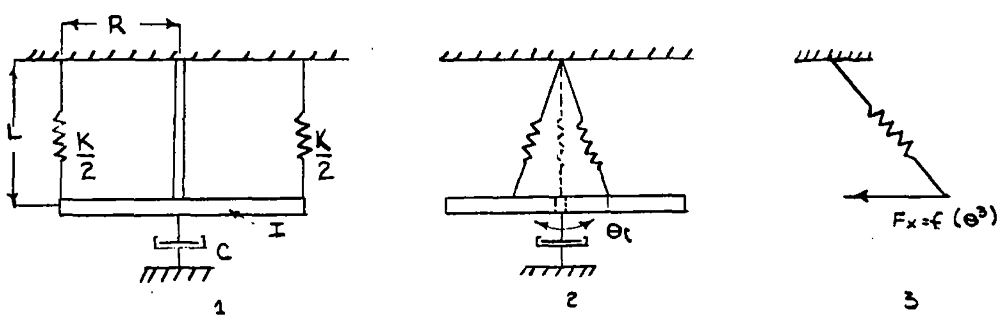
2 - EVALUATE THE EXTENT TO WHICH LINEAR ALGORITHMS CAN PROVIDE USEFUL INFORMATION ON NONLINEAR SYSTEMS.

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

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

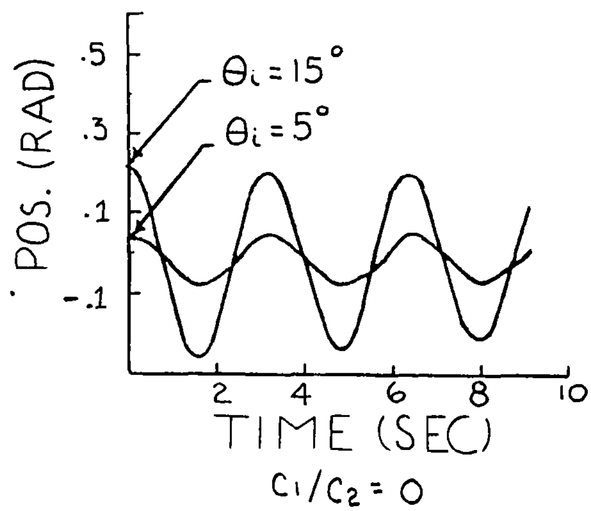
GENERAL FORM

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

LINEAR NATURAL FREQUENCY = 0.288 HZ

LINEAR MODAL DAMPING = 0.01

SINGLE DEGREE OF FREEDOM RESPONSE



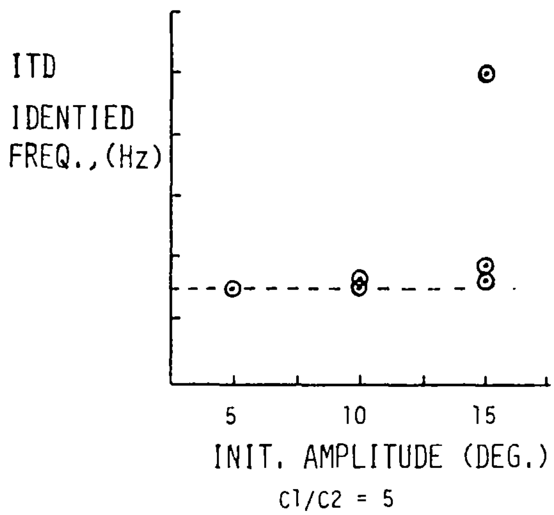

THE IBRAHIM-TIME-DOMAIN (ITD) MODAL DATA ANALYSIS METHOD

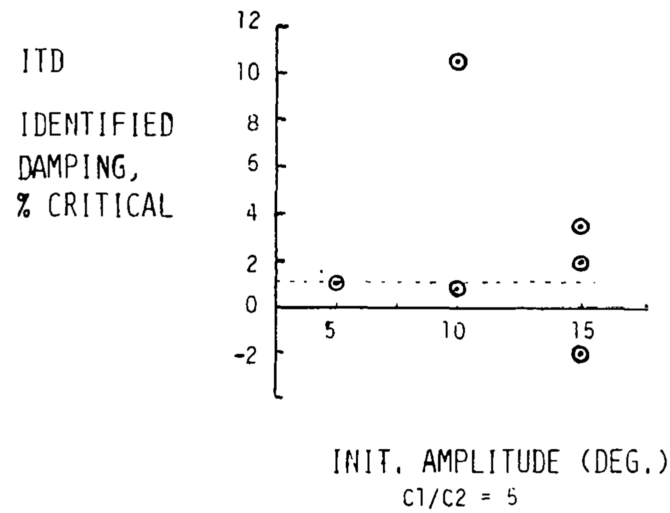
O AN OFF-LINE LARGE-SCALE DATA ANALYSIS METHOD DEVELOPED FOR STRUCTURAL DYNAMICS TESTS.

O OPERATES ON FREE-DECAY RESPONSES SOLVING MANY DATA CHANNELS SIMULTANEOUSLY.

O HAS PROVEN MORE SUCCESSFUL THAN OTHER LABORATORY METHODS FOR HANDLING NOISE, LARGE SYSTEMS, AND CLOSELY SPACED MODES.

## SINGLE DEGREE OF FREEDOM RESULTS



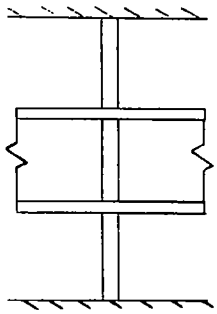

## SINGLE DEGREE OF FREEDOM RESULTS COMPARISON

| | $F_1$ (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  IC = 10°

## TWO DEGREE OF FREEDOM ANALYTICAL MODEL

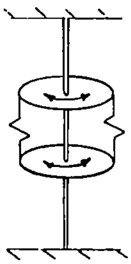
SYSTEM



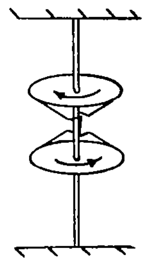
EQUATION OF MOTION

$$\begin{bmatrix} I_1 & 0 \\ 0 & I_2\end{bmatrix}\begin{Bmatrix}\ddot\theta_1\\ \ddot\theta_2\end{Bmatrix} + \begin{bmatrix} C_{11} & -C_{12} \\ -C_{21} & C_{22}\end{bmatrix}\begin{Bmatrix}\dot\theta_1\\ \dot\theta_2\end{Bmatrix} + \begin{bmatrix} K_{11} & -K_{12}\\ -K_{21} & K_{22}\end{bmatrix}\begin{Bmatrix}\theta_1\\ \theta_2\end{Bmatrix}$$

$$+ \begin{bmatrix}\varepsilon & 0\\ 0 & -\varepsilon\end{bmatrix}\begin{Bmatrix}(\theta_1-\theta_2)^3\\(\theta_1-\theta_2)^3\end{Bmatrix} = \begin{Bmatrix}0\\0\end{Bmatrix}$$

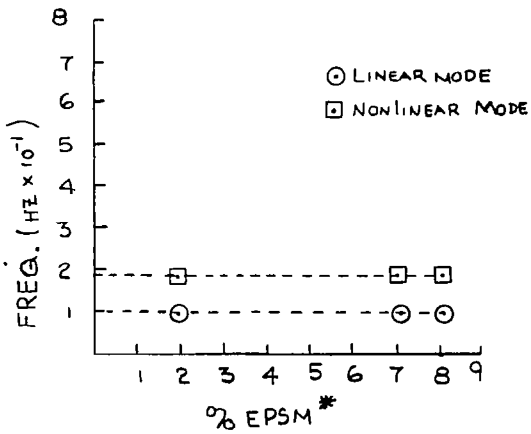


LINEAR MODE
$F_1 = .100$ HZ

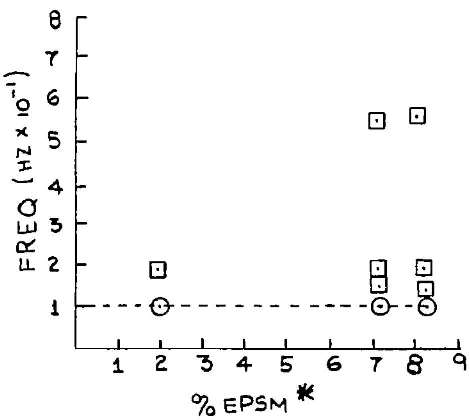


NON LINEAR MODE
$F_2 = .199$ HZ

## 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.