Раздел 8

Анализ частотного отклика

Раздел 8. Анализ частотного оклика

Анализ частотного оклика (продолж.)

Введение в анализ частотного отклика

- Вычисление отклика на гармоническое воздействие.
- Воздействие в явной форме определено в частотной области – величины всех прилагаемых силовых факторов известны на всех частотах.
- Обычно вычисляются узловые перемещения, а также силы и напряжения в элементах.
- Результаты решения – комплексные величины: амплитуда и фаза (относительно воздействия) или действительная и мнимая часть отклика.
- Два типа анализа – прямой и модальный.

Прямой метод анализа

- **Уравнение колебаний:**
- $$[-\omega^2 M + i\omega B + K]\{u(\omega)\} = \{P(\omega)\} \quad (1)$$
- **Параметры PARAM,G и GE в операторе MATi формируют не матрицу демпфирования, а комплексную матрицу жесткости**
- $$K = (1 + iG)K^1 + i\sum G_E k_E \quad (2)$$
- **где** K^1 **– глобальная матрица жесткости**
- **G – коэффициент глобального конструкционного**
- **демпфирования (PARAM,G)**
- K_E **– матрица жесткости элемента**
- G_E **– коэффициент конструкционного демпфирования**
- **элемента (параметр GE в операторе MATi)**
- **Сравните с анализом переходного процесса**

$$B_{TRANS} = B^1 + B^2 + \frac{G}{W_3}K^1 + \frac{1}{W_4}\sum G_E k_E$$

- **Выражение (2) подставляется в уравнение (1), а затем оно решается аналогично статической задаче (с использованием комплексной арифметики).**

Модальный метод анализа

- Физические координаты конвертируются в модальные, а затем анализируются несвязанные системы с одной степенью свободы (СС)

$$\xi_i = \frac{P_i}{-m_i\omega^2 + ib_i\omega + k_i}$$

- Решение выполняется много быстрее, чем прямым методом
- Уравнения несвязанные, если присутствует только модальное демпфирование (задаваемое оператором TABDMP1) или его нет совсем . В противном случае, если есть немодальное демпфирование (элементы VISC, DAMP), то для решения используется менее эффективный прямой подход (однако, все же, на небольших модальных матрицах).

Задание внешнего воздействия

- Внешнее воздействие задается как функция частоты.
- В MSC.Nastran предусматриваются различные методы:
  - RLOAD1 (задание воздействия в виде действительной и мнимой компонент)
  - RLOAD2 (задание воздействия в форме амплитуды и фазы)
  - LSEQ (конвертация статических нагрузок в динамические)
- Оператор DLOAD в Bulk Data Section используется для комбинирования частотно-зависимых нагрузок.
- Операторы RLOADi инициируются оператором DLOAD в Case Control Section.

Defines a frequency-dependent dynamic load of the form

$$\{P(f)\} = \{A[C(f) + iD(f)]e^{i\{\theta - 2pf\tau\}}\}$$

for use in frequency response problems.

Format:

1	2	3	4	5	6	7	8	9	10
RLOAD1	SID	DAREA	DELAY	DPHASE	TC	TD			

Example:

RLOAD1	5	3			1				

Field	Contents
SID	Set identification number. (Integer > 0)
DAREA	Identification number of the DAREA entry set that defines A. (integer > 0)
DELAY	Identification number of the DELAY entry set that defines τ. (Integer $\geq$ 0)
DPHASE	Identification number of the DPHASE entry set that defines θ. (Integer $\geq$ 0)
TC	Set identification number of the TABLEDi entry that gives C(f). See Remark 2. (Integer $\geq$ 0)
TD	Set identification number of the TABLEDi entry that gives D(f). See Remark 2. (Integer $\geq$ 0)

Remarks:

1. Dynamic load sets must be selected with the Case Control command DLOAD=SID.
2. If any of DELAY, DPHASE, TC, or TD fields are blank or zero, the corresponding t, q, C(f), or D(f) will both be zero. Either TC or TD may be blank or zero, but not both.
3. RLOAD1 loads may be combined with RLOAD2 loads only by specification on a DLOAD entry. That is, the SID on a RLOAD1 entry must not be the same as that on a RLOAD2 entry.
4. SID must be unique for all RLOAD1, RLOAD2, TLOAD1, and TLOAD2 entries.

Defines a frequency-dependent dynamic load of the form

$$\{P(f)\} = \{A*B(f)e^{i\{\phi(f) + \theta - 2\pi f\tau\}}\}$$

for use in frequency response problems.

Format:

1	2	3	4	5	6	7	8	9	10
RLOAD2	SID	DAREA	DELAY	DPHASE	TB	TP			

Example:

RLOAD2	5	3			7				

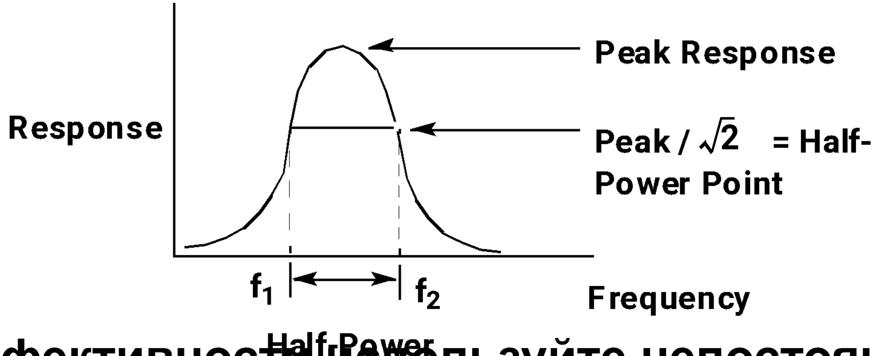
Field	**Contents**
SID	Set identification number. (Integer > 0)
DAREA	Identification number of the DAREA entry set that defines A. (integer > 0)
DELAY	Identification number of the DELAY entry set that defines t. (Integer ≥ 0)
DPHASE	Identification number of the DPHASE entry set that defines q in degrees. (Integer ≥ 0)
TB	Set identification number of the TABLEDi entry that gives B(f). (Integer ≥ 0)
TP	Set identification number of the TABLEDi entry that gives f(f) in degrees. (Integer ≥ 0)

Remarks:

1. Dynamic load sets must be selected with the Case Control command DLOAD=SID.
2. If any of DELAY, DPHASE, or TP fields are blank or zero, the corresponding t, q, B(f), or f(f) will be
3. RLOA21 loads may be combined with RLOAD1 loads only by specification on a DLOAD entry. That is, the SID on a RLOAD2 entry must not be the same as that on a RLOAD1 entry.
4. SID must be unique for all RLOAD1, RLOAD2, TLOAD1, and TLOAD2 entries.

Замечания к анализу частотного отклика

- Воздействие на систему без демпфирования (или с модальным демпфированием) с частотой 0 Гц приводит к результатам, аналогичным статическому нагружению. Поэтому, если частота воздействия много меньше частот собственных колебаний конструкции, достаточно статического расчета.
- Системы с очень малым демпфированием на частотах, близких к резонансным, дают большие отклики. Небольшие изменения в расчетной модели (или даже выполнение расчета на другой ЭВМ) может привести к значительным переменам в результатах.
- Необходимо правильно выбирать шаг по частоте (Δf) чтобы иметь адекватные результаты. Используйте, по крайней мере, 5 “точек” в полосе половинной мощности.



- Для большей эффективности используйте непостоянный шаг: меньший Δf вблизи резонансных частот и больший Δf вдали от них.

Операторы FREQi

- Задают шаг по частоте.
- Оператор FREQ задает дискретные значения частот воздействия.
- Оператор FREQ1 задает начальное значение частоты, инкремент (шаг) и число инкрементов (шагов).
- Оператор FREQ2 задает начальное и конечное значения частоты, а также количество логарифмических интервалов.
- Оператор FREQ3 задает частоты F1, F2 и количество частот воздействия между F1, собственными частотам конструкции и F2. Допускает неравномерную разбивку интервалов.
- Оператор FREQ4 задает частоты F1 и F2, частотный диапазон и количество частот воздействия “около” каждой из собственных частот конструкции, “попадающих” в диапазон (F1,F2).
- Оператор FREQ5 задает частоты F1 и F2 и *доли* собственных частот конструкции, на которых будет вычисляться воздействие, если они (вычисленные частоты) находятся в диапазоне (F1,F2).
- Операторы FREQ3, FREQ4 и FREQ5 применимы только при модальном методе анализа.

Операторы FREQi

- Операторы FREQi вBulk Data Section инициируются оператором FREQUENCY в Case Control Section.
- Все операторы FREQi в Bulk Data Section, имеющие одинаковый идентификатор, инициируются одним оператором FREQUENCY в Case Control Section. Следовательно, операторы FREQ, FREQ1, FREQ2, FREQ3, FREQ4 и FREQ5 могут использоваться одновременно.

Defines a set of frequencies to be used in the solution of frequency response problems.

Format

1	2	3	4	5	6	7	8	9	10
FREQ	SID	F1	F2	F3	F4	F5	F6	F7	
	F8	F9	F10	-etc.-					

Example:

FREQ	3	2.98	3.05	17.9	21.3	25.6	28.8	31.2	
	29.2	22.4	19.3						

Field	**Contents**
SID	Set identification number. (Integer > 0)
Fi	Frequency value in units of cycles per unit time. (Real ≥ 0.0)

Remarks:

1. Frequency sets must be selected with the Case Control command FREQUENCY = SID.
2. All FREQi entries with the same frequency set identification numbers will be used. Duplicate frequencies will be ignored. f_N and f_{N-1} are considered duplicated if $|f_N - f_{N-1}| < DFREQ * |f_{MAX} - f_{MIN}|$, where DFREQ is a user parameter, with default of 10-5. f
3. In modal analysis, solutions for modal DOFs from rigid body modes at zero excitation frequencies may be discarded. Solutions for nonzero modes are retained.

Defines a set of frequencies to be used in the solution of frequency response problems by specification of a starting frequency, frequency increment, and the number of increments desired..

Format:

1	2	3	4	5	6	7	8	9	10
FREQ1	SID	F1	DF	NDF					

Example:

FREQ1	6	2.9	0.5	13					

Field	Contents
SID	Set identification number. (Integer > 0)
F1	First frequency set. (Real 0.0)
DF	Frequency increment. (Real > 0.0)
NDF	Number of frequency increments. (Integer > 0; Default = 1)

Remarks:

1. FREQ1 entries must be selected with the Case Control command FREQUENCY = SID.
2. The units for F1 and DF are cycles per unit time.
3. The frequencies defined by this entry are given by

$$f_i = F1 + DF * (i - 1)$$

   where i = 1 to (NDF + 1)
4. All FREQi entries with the same frequency set identification numbers will be used. Duplicate frequencies will be ignored. f_N and f_{N-1} are considered duplicated if $|f_N - f_{N-1}| < DFREQ * |f_{MAX} - f_{MIN}|$, where DFREQ is a user parameter, with default of 10-5. f_{MAX} and f_{MIN} are the maximum and minimum excitation frequencies of the combined FREQi entries.
5. In modal analysis, solutions for modal DOFs from rigid body modes at zero excitation frequencies may be discarded. Solutions for nonzero modes are retained.

(Continued)

Defines a set of frequencies to be used in the solution of frequency response problems by specification of a starting frequency, final frequency, and the number of logarithmic increments desired..

Format:

1	2	3	4	5	6	7	8	9	10
FREQ2	SID	F1	F2	NF					

Example:

FREQ2	6	1	8	6					

Field	Contents
SID	Set identification number. (Integer > 0)
F1	First frequency. (Real > 0.0)
F2	Last frequency. (Real > 0.0, F2 > F1)
NF	Number of logarithmic intervals. (Integer > 0; Default = 1)

Remarks:

1. FREQ2 entries must be selected with the Case Control command FREQUENCY = SID.
2. The units for F1 and F2 are cycles per unit time.
3. The frequencies defined by this entry are given by

$$f_i = F1 * e^{(i-1)d}$$

where d = (1/NF) * ln (F2/F1) and i = 1, 2, . . . , (NF + 1)

In the example above, the list of frequencies will be 1.0, 1.4142, 2.0, 2.8284, 4.0, 5.6569, and 8.0 cycles per unit time

$$\frac{f_{i+1}}{f_i} = e^d = \left(\frac{F_2}{F_1}\right)^{\frac{1}{N_F}}$$

4. All FREQi entries with the same frequency set identification numbers will be used. Duplicate frequencies will be ignored. f_N and f_{N-1} are considered duplicated if $|f_N - f_{N-1}| < DFREQ*|f_{MAX} - f_{MIN}|$, where DFREQ is a user parameter, with default of 10-5. f

5. In modal analysis, solutions for modal DOFs from rigid body modes at zero excitation frequencies may be discarded. Solutions for nonzero modes are retained.

(Continued)

Defines a set of excitation frequencies for modal frequency response solutions by speciying a number of excitation frequencies between two modal frequencies.

Format:

1	2	3	4	5	6	7	8	9	10
FREQ3	SID	F1	F2	TYPE	NEF	CLUSTER			

Example:

FREQ3	6	20	2000	LINEAR	10	2			

Field	Contents
SID	Set identification number. (Integer > 0)
F1	Lower bound of modal frequency range in cycles per unit time. (Real > 0.0)
F2	Upper bound of modal frequency range in cycles per unit time. (Real>0.0, F2F1, Default
TYPE	LINEAR or LOG. Specifies linear or logarithmic interpolation between frequencies. (Character; Default = "LINEAR")
NEF	Number of excitation frequencies within each subrange including the end points. The first subrange is between F1 and the first modal frequency within the bounds. The second subrange is between first and second modal frequencies between the bounds. The
CLUSTER	Specifies clustering of the excitation frequency near the end points of the range.See Remark3. (Real > 0.0; Default=1.0)

Remarks:

1. FREQ3 applies only to modal frequency-response solutions (SOLs 11, 111, 146, and 200) and is ignored in direct frequency response solutions.
2. FREQ3 entries must be selected with the Case Control command FREQUENCY = SID.
3. In the example above, there will be 10 frequencies in the interval between each set of modes within the bounds 20 and 2000, plus 10 frequencies between 20 and the lowest mode in the range, plus 10 frequencies between the highest mode in the range and 2000
4. Since the forcing frequencies are near structural resonances, it is important that some amount of damping be specified.

(Continued)

Defines a set of frequencies used in the solution of modal frequency-response problems by specifying the amount of "spread" around each natural frequency and the number of equally spaced excitation frequencies

Format

1	2	3	4	5	6	7	8	9	10
FREQ4	SID	F1	F2	FSPD	NFM				

Example:

FREQ4	6	20	200	0.3	21				

Field	Contents
SID	Set identification number. (Integer > 0)
F1	Lower bound of frequency range in cycles per unit time. (Real ≥ 0.0, Default=0.0)
F2	Upper bound of frequency range in cycles per unit time. (Real>0.0, F2 ≥ F1, Default = 1
FSPD	Frequency spread, +/- the fractional amount specified for each mode which occurs un the frequency range F1 to F2. (1.0 > Real > 0.0; Default = 0.10)
NFM	Number of evenly spaced frequencies per "spread" mode.. (Integer > 0; Default = 3; If NFM is even, NFM + 1 will be used.)

Remarks:

1. FREQ4 applies only to modal frequency-response solutions (SOLs 11, 111, 146, and 200) and is ignored in direct frequency response solutions.
2. FREQ4 entries must be selected with the Case Control command FREQUENCY = SID.
3. There will be NFM excitation frequencies between (1-FSPD) * f_N and (1+FSPD) * f_N, for each natural frequency in the range F1 to F2.
4. In the example above there will be 21 equally spaced frequencies across a frequency band of 0.7 * f_N to 1.3 * f_N for each natural frequency that occurs between 20 and 2000. See Figure 1 for defintion of frequency spread.

(Continued)

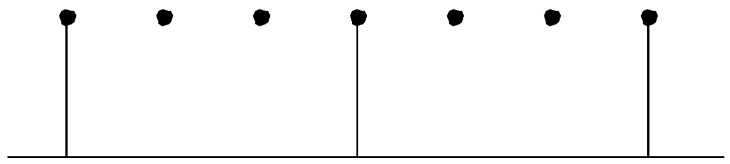


Figure 1. Frequency Spread Definition

Excitation frequencies may be based on natural frequencies that are not within the range (F1 and F2) as long as the calculated excitation frequencies are within the calculated range. Similarly, an excitation frequency calculated based on the natural frequencies within the range (F1through F2) may be excluded if it falls outside the range.

5. The frequency spread can also be used to define the half-power bandwidth. The half-poer bandwidth is given by 2 * x * fN, where x is the damping ratio. Therefore, if FSPD is specified equal to the damping ratio for the mode, NFM specifies the number of excitation frequency within the half-power bandwidth. See Figure 2 for the definition of half-power bandwidth.

(Continued)

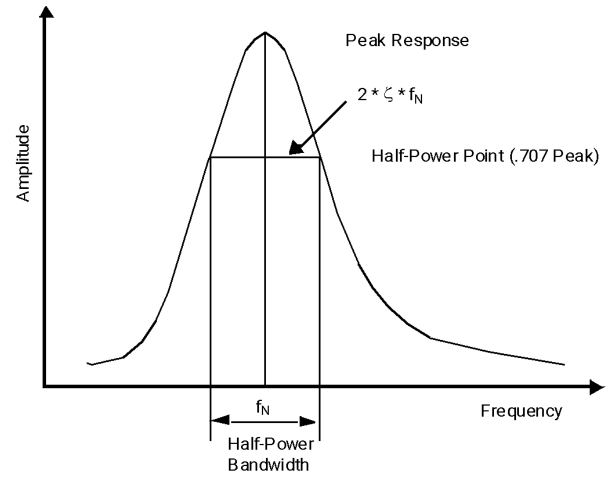


Figure 2. Half-Power Bandwidth Definition

6. Since the forcing frequencies are near structural resonances, it is important that some amount of damping be specified.
7. All FREQi entries with the same frequency set identification numbers will be used. Duplicate frequencies will be ignored. f_N and f_{N-1} are considered duplicated if

$$|f_N - f_{N-1}| < DFREQ * |f_{MAX} - f_{MIN}|,$$

where DFREQ is a user parameter, with default of 10-5. f_{MAX} and f_{MIN} are the maximum and minimum excitation frequencies of the combined FREQi entries.
8. In design optimization, (SOL 200), the excitation frequencies generated from this entry are derived from the natural frequencies computed in the first design cycle and the ecitation frequencies remain fixed through subsequent design cycles. In other word
9. In modal analysis, solutions for modal DOFs from rigid body modes at zero excitation frequencies may be discarded. Solutions for nonzero modes are retained.

(Continued)

Defines a set of frequencies used in the solution of modal frequency-response problems by speciification of a frequency range and fractions of the natural frequencies within that range.

Format:

1	2	3	4	5	6	7	8	9	10
FREQ5	SID	F1	F2	FR1	FR2	FR3	FR4	FR5	
	FR6	FR7	-etc.-						

Example:

FREQ5	6	20	200	1	0.6	0.8	0.9	0.95	
	1.05	1.1	1.2						

Field	**Contents**
SID	Set identification number. (Integer > 0)
F1	Lower bound of frequency range in cycles per unit time. (Real ≥ 0.0, Default=0.0)
F2	Upper bound of frequency range in cycles per unit time. (Real>0.0, F2 ≥ F1, Default = 1.0E20)
FRi	Fractions of the natural frequencies in the range F1 to F2 (Real > 0.0)

Remarks:

1. FREQ5 applies only to modal frequency-response solutions (SOLs 11, 111, 146, and 200) and is ignored in direct frequency response solutions.
2. FREQ5 entries must be selected with the Case Control command FREQUENCY = SID.
3. The frequencies defined by this entry are given by

$$f_i = FR_i * f_{Ni}$$

   where f_{Ni} are the natural frequencies in the range F1 through F2.
4. In the example above, the list of frequencies will be 0.6, 0.8, 0.9, 0.95, 1.0, 1.05, 1.1, 1.2 times each natural frequency [illegible] between 20 and 2000. If this computation results in excitation frequencies less than F1 and greater than F2, those computed frequencies are ignored.

(Continued)

5. Since the forcing frequencies are near structural resonances, it is important that some amount of damping be specified.

6. All FREQi entries with the same frequency set identification numbers will be used. Duplicate frequencies will be ignored. f_N and f_{N-1} are considered duplicated if

$$|f_N - f_{N-1}| < DFREQ * |f_{MAX} - f_{MIN}|,$$

where DFREQ is a user parameter, with default of 10^{-5}. f_{MAX} and f_{MIN} are the maximum and minimum excitation frequencies of the combined FREQi entries.

7. In design optimization, (SOL 200), the excitation frequencies generated from this entry are derived from the natural frequencies computed in the first design cycle and the ecitation frequencies remain fixed through subsequent design cycles. In other words, the excitation frequencies will not be readjusted even if the natural frequencies change.

8. In modal analysis, solutions for modal DOFs from rigid body modes at zero excitation frequencies may be discarded. Solutions for nonzero modes are retained.

(Continued)

Методы вычисления результатов

- Предусмотрены два метода вычисления результатов при модальном анализе: метод модальных перемещений и матричный метод.

$$\frac{\text{Cost of matrix method}}{\text{Cost of mode displacement method}} = \frac{H}{F}$$

- где H – количество мод
- F – количество частот воздействия
- Матричный метод задан “по умолчанию”, он менее затратен при H < F и рекомендуется к применению в большинстве случаев.
- Метод модальных перемещений может быть инициирован с помощью параметра PARAM,DDRMM,-1.

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Применение модального и прямого методов

	Modal	Direct
Small Model		X
Large Model	X	
Few Excitation Frequencies		X
Many Excitation Frequencies	X	

Форматы вывода SORT1 и SORT2

- SORT1: для частоты воздействия выводятся результаты по всем узлам и элементам, затем для другой частоты и т.д.
- SORT2: для узла (элемента) выводятся результаты по всем частотам, затем для другого узла (элемента) и т.д.
- Рекомендации по использованию

	Transient Response		Frequency Response	
	Direct	Modal	Direct	Modal
Default	2	2	1	1
Deformed Plot Requests	1	1	1	1
XY Plot Requests	2	2	2	2

- Если указана “смесь” форматов SORT1 и SORT2, то “по умолчанию”при анализе частотного отклика будет использован SORT1, а переходного процесса - SORT2.

Управление решением при анализе частотного отклика

- Executive Control Section
- SOL <см. таблицу>

Method	Structured Soultion Sequences
Direct	108
Modal	111

- Case Control Section
- DLOAD (требуется при обоих методах решения)
- LOADSET (может применяться при обоих методах)
- METHOD (требуется при модальном методе)
- SDAMPING(может применяться при модальном методе)
- FREQUENCY (требуется при обоих методах решения)

Управление решением при анализе частотного отклика

- Bulk Data Section
  - ASET,OMIT (может применяться при обоих методах)
  - EIGRL or EIGR (требуется при модальном методе)
  - FREQ (требуется при обоих методах решения)
  - RLOADi (требуется при обоих методах решения)
  - LSEQ (может применяться при обоих методах)
  - DAREA (требуется при обоих методах решения*)
  - DELAY (может применяться при обоих методах)
  - DPHASE (может применяться при обоих методах)
  - TABDMP1 (может применяться при модальном методе)
  - DLOAD (может применяться при обоих методах)
- **Идентификатор* оператора DAREA необходим; если же применяется оператор LSEQ, то сам оператор DAREA может отсутствовать.

Виды вычисляемых величин

- Результаты вычислений для узлов
  - ACCELERATION
  - DISPLACEMENT (или VECTOR)
  - OLOAD
  - SACCELERATION
  - SDISPLACEMENT
  - SVELOCITY
  - SVECTOR
  - SPCFORCES
  - VELOCITY
  - MPCFORCE
- Результаты вычислений для элементов
  - ELSTRESS (или STRESS)
  - ELFORCE (или FORCE)
  - STRAIN
  - ESE
  - EKE
  - EDE
- Специальный оператор
  - OFREQUENCY (задание частот, для которых должны выводиться результаты; работает совместно с оператором FREQUENCY)

Частотно-зависимые пружины и демпферы

- Жесткость зависит от частоты воздействия
- Демпфирование зависит от частоты воздействия
- Различный импеданс в различных направлениях
- Оператор CBUSH
  - Задание топологии элемента
- Оператор PBUSH
  - Задание основных свойств элемента (не частотно-зависимых)
- Оператор PBUSHT
  - Задание частотно-зависимых свойств элемента

Defines a generalized spring-and-damper structural element that may be nonlinear or frequency dependent.

Format:

1	2	3	4	5	6	7	8	9	10
CBUSH	EID	PID	GA	GB	GO/X1	X2	X3	CID	
	S	OCID	S1	S2	S3				

Example 1: Noncoincident grid points.

CBUSH	39	6	1	100	75				

Example 2: GB not specified.

CBUSH	39	6	1					0	

Example 3: Coincident grid points (GA = GB).

CBUSH	39	6	1	100				6	

Example 4: Noncoincident grid points with fields 6 through 9 blank and a spring-damper offset.

CBUSH	39	6	1	600				6	
	0.25	10	0	10	10				

Field	Contents
EID	Element identification number. (Integer > 0)
PID	Property identification number of a PBUSH entry. (Integer>0; Default=EID)
GA, GB	Grid point identification number of connections points. See Remark 6. (Integer > 0)
Xi	Components of orientation vector $\vec{V}$, from GA, in the displacement coordinate system at GA. (Real)
GO	Alternate method to supply vector $\vec{V}$ using grid point GO. Direction of $\vec{V}$ is from GA to GO. $\vec{V}$ is then transferred to End A. See Remark 3. (Integer > 0)
CID	Element coordinate system identification. A 0 means the basic coordinate system. If CID is blank, then the element coordinate system is determined from GO or Xi. See Figure 1 and Remark 3. (Integer ≥ 0 or blank)

(Continued)

S — Location of spring damper. See Figure 2. (0.0 < Real < 1.0; Default = 0.5)

OCID — Coordinate system identification of spring-damper offset. See Remark 9. (Integer ≥ ~~0~~1; Default=-1 which means element coordinate system)

S1, S2, S3 — Components of spring-damper offset in the OCID coordinate system if OCID > 0. See Figure 2 and Remark 9. (Real)

Remarks:

1. Element identification numbers must be unique with respect to all other element identification
2. Figure 1shows the bush element geometry
3. CID ≥ 0 overrides GO and Xi.
4. For noncoincident grids (GA ≠ GB), when GO or (X1, X2, X3) is given and no CID is specified, the line AB is the element x-axis and the orientation vector lies in the x-y plane (similar to the
5. For noncoincident grids (GA ≠ GB), if neither GO or (X1, X2, X3) is specified and no CID is specified, then the line AB is the element x-axis. This option is valid only when K1 (or B1) or K4 (or B4) or both on the PBUSH entry are specified (but K2, K3, K5, K6 or B2, B3, B5, B6 are not specified). If K2, K3, K5, or K6 (or B2, B3, B5, or B6) are specified, a fatal message will be
6. If GA and GB are coincident, or if GB is blank, then CID must be specified.
7. If PID references a PBUSHT entry, then the CBUSH element may only be defined in the residual structure and cannotbe attached to any omitted degrees of freedom.
8. Element impedance output is computed in the CID coordinate system. The impedances in this system are uncoupled.
9. If OCID = -1 or blank (default) then S is used and S1, S2, S3 are ignored. If OCID ≥ 0, then S is ignored and S1, S2, S3 are used.

(Continued)

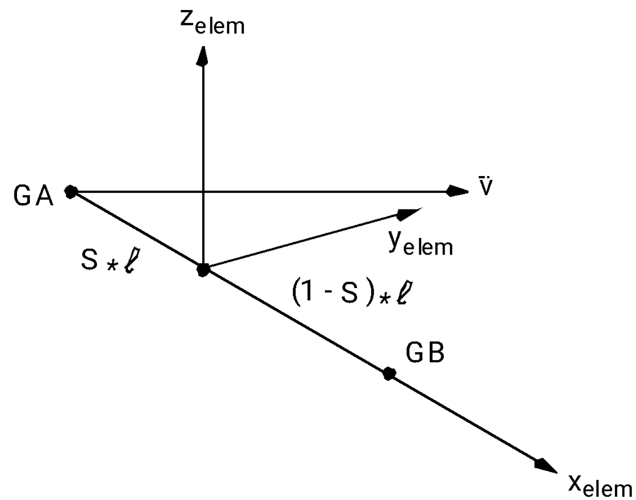
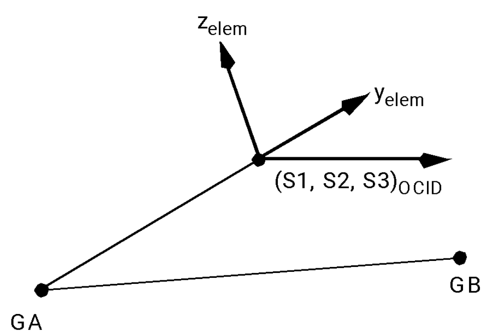


Figure 1. CBUSH Element.



Note: 1. The material stiffness and damping properties of the elastomer are located at (S1, S2, S3).
2. The elastomer itself has zero length; i.e., GA and GB are coincident. It is shown here in an exploded view

Figure 2. Definition of Offset S1, S2, S3

Defines the nominal property values for a generalized spring-and-damper structural element.

Format

1	2	3	4	5	6	7	8	9	10
PBUSH	PID	K	K1	K2	K3	K4	K5	K6	
		B	B1	B2	B3	B4	B5	B6	
		GE	GE1						
		RCV	SA	ST	EA	ET			

Example 1: Stiffness and structural damping are specified.

PBUSH	35	K	4.35	2.4				3.1	
		GE	0.06						
		RCV	7.3	3.3					

Example 2: Damping force per unit velocity are specified.

PBUSH	35	B	2.3						

Field	Contents
PID	Property identification number. (Integer > 0)
K	Flag indicating that next 1 to 6 fields are stiffness values. (Character)
Ki	Nominal stiffness values in directions 1 through 6. (Real; Default=0.0)
B	Flag indicating that the next 1 to 6 fields are force-per-velcoity damping. (Character)
Bi	Nominal damping cofficient in units of force per unit velocity. (Real; Default=0.0)
GE	Flag indicating that the next fields is structural damping. (Character)
GE1	Nominal Structural damping constant. (Real;Default=0.0)
RCV	Flag indicating that the next 1 to 4 fields are stress or strain coefficients. (Character)
SA	Stress recovery coefficient in the translational component numbers 1 through 3. (Real' Default=1.0)

(Continued)

ST	Stress recovery coefficient in the rotational component numbers 4 through 6. (Real; Default=1.0)
EA	Strain recovery coefficient in the translational component numbers 1 thorough 3. (Real; Default=1.(
ET	Strain recovery coefficient in the rotational component numbers 4 through 6. (Real; Default=1.0)

Remarks:

1. Ki, Bi, or GE1 may be made frequency dependent for both direct and modal frequency response by use of PBUSHT entry.
2. The nominal values are used for all analysis types except frequency response. For modal frequency response, the normal modes are computed using the nominal Ki values. The frequency-dependent values are used at every excitation frequency.
3. If PARAM,W4 is not specified, GE1 ignored in transient analysis.
4. The elements stresses are computed by multiplying the stress coefficinets with the recovered element forces.
5. The element strains are computed by multiplying the strain coefficients with the recovered element displacments.
6. The "K", "B", "GE", or "RCV" entries may be specified in any order.

(Continued)

Defines the frequency-dependent properties or the force-dependent properties for a generalized spring-and-damper structural element.

Format:

1	2	3	4	5	6	7	8	9	10
PBUSHT	PID	K	TKID1	TKID2	TKID3	TKID4	TKID5	TKID6	
		B	TBID1	TBID2	TBID3	TBID4	TBID5	TBID6	
		GE	TGEID1						
		KN	TKNID1	TKNID2	TKNID3	TKNID4	TKNID5	TKNID6	

Example:

PBUSHT	35	K	72						
		E	18						

Field	Contents
PID	Property identification number that matches the identification number on a PBUSH entryr. (Integer
K	Flag indicating that next 1 to 6 fields are stiffness frequency table identification numbers in directions 1 through 6. (Character)
TKIDi	Identification number of a TABLEDi entry that defines the stiffness versus frequency relationship in directions 1 through 6 (Integer ≥ 0; Default = 0)
B	Flag indicating that the next 1 to 6 fields are force per velocity-frequency table identification numbers.. (Character)
TBIDi	Identification number of a TABLEDi entry that defines the damping force per unit velocity versus frequency relationshis in directions 1 through 6 (Integer ≥ 0; Default = 0)
GE	Flag indicating that the next field is a structural damping frequency table identification number. (Character)
TGEIDi	Identification number of a TABLEDi entry that defines the nondimensional structural damping versus frequency relationshis in directions 1 through 6 (Integer ≥ 0; Default = 0)
KN	Flag indicating that the next 1 to 6 fields specifiy TABLEDi identification numbers for the force versus deflection relationship.
TKNIDi	Identification number of a TABLEDi entry that defines the force versus deflection relationshis in directions 1 through 6 (Integer ≥ 0; Default = 0)

(Continued)

Remarks:

1. The "K", "B", and "GE" entries are associated with the same entries on the PBUSH entry
2. PBUSHT may only be referenced by CBUSH elements in the residual structure, which do not attach to any omitted degrees of freedom.
3. The nominal values are used for all analysis types except frequency-response and nonlinear analyses. For frequency-dependent modal frequency respponse, the system modes are computed using the nominal Ki values. The frequency-dependent values are used at
4. The "K", "B", "GE", and "KN" entries may be specified in any order.
5 The PBUSHT entry is ignored in all solution sequences except frequency-response or nonlinear

(Continued)

Пример частотно-зависимого импеданса

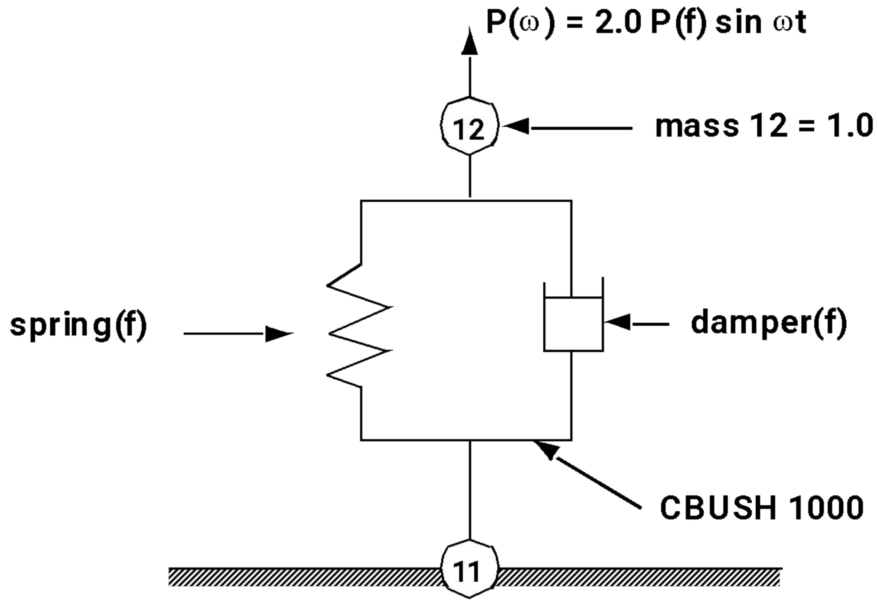


Table of Impedance

Forcing Frequency (Hz)	K(f)	B(f)	P(f)
0.9	0.81	0.286479	0.81
1	1	0.31831	1
1.1	1.21	0.350141	1.21

Пример использования элемента CBUSH

```
$
$        cbush1.dat
$
TIME 10
SOL 108
CEND
TITLE = VERIFICATION PROBLEM, FREQ. DEP. IMPEDANCE              BUSHVER
SUBTITLE = SINGLE DOF, CRITICAL DAMPING, 3 EXCITATION FREQUENCIES
ECHO = BOTH
SPC = 1002
DLOAD = 1
DISP = ALL
FREQ = 10
ELFO = ALL
BEGIN BULK
$ CONVENTIONAL INPUT FOR MOUNT
GRDSET,  ,        ,        ,        ,        ,        ,        23456 $ PS
$ TIE DOWN EVERYTHING BUT THE 1 DOF
GRID,    11,      ,        0.,      0.,      0.0      $ GROUND
=,       12,      =,       =,       =,       ,        $ ISOLATED DOF
SPC1,    1002     123456   11       $ GROUND
CONM2,   12,      12,      ,        1.0      $ THE ISOLATED MASS
$
$        EID      PID      GA       GB       GO/X1    X2       X3       CID
$
CBUSH    1000     2000     11       12                                  0
$
PBUSH    2000     K        1.0
                  B        0.0
$
PBUSHT   2000     K        2001
                  B        2002
$
TABLED1, 2001 $ STIFFNESS TABLE
,        0.9      0.81,    1.0,     1.0,     1.1,     1.21     ENDT
TABLED1 2002 $ DAMPING TABLE
,        0.9      .2864789, 1.0,             .318309,   1.1    ,        .3501409  ENDT
$CONVENTIONAL INPUT FOR FREQUENCY RESPONSE
PARAM,   WTMASS,  .0253303 $ 1/(2*PI)**2. GIVES FN=1.0
DAREA,   1,       12,      1,       2.  $CAUSES UNIT DEFLECTION
FREQ,    10,      0.9,     1.0,     1.1  $  BRACKET THE NATURAL FREQUENCY
RLOAD1,  1,       1,       ,        ,        3
TABLED1,3  $  TABLE FOR FORCE VS. FREQUENCY
,        0.9,     0.81,    1.,      1.,      1.1,     1.21,ENDT  $ P = K
ENDDATA
```

Результаты расчета перемещений для элемента CBUSH

```
FREQUENCY =   9.000000E-01
       C O M P L E X     D I S P L A C E M E N T
       (REAL/IMAGINARY)

       POINT ID.      TYPE    T1      T2      T3      R1      R2      R3
0      11      G      .0      .0      .0      .0      .0      .0
                      .0      .0      .0      .0      .0      .0
0      12      G      -6.682744E-08  .0      .0      .0      .0      .0
                      -1.000000E+00  .0      .0      .0      .0      .0
1      VERIFICATION PROBLEM, FREQ. DEP. IMPEDANCE                  BUSHVER MARCH 20,1997 MSC.Nastran 1/23/97 PAGE 8
        SINGLE DOF , CRITICAL DAMPING, 3 EXCITATION FREQUENCIES
0
FREQUENCY =   1.000000E+00
       C O M P L E X     D I S P L A C E M E N T
       (REAL/IMAGINARY)

       POINT ID.      TYPE    T1      T2      T3      R1      R2      R3
0      11      G      .0      .0      .0      .0      .0      .0
                      .0      .0      .0      .0      .0      .0
0      12      G      -1.046835E-07  .0      .0      .0      .0      .0
                      -9.999999E-01  .0      .0      .0      .0      .0
1      VERIFICATION PROBLEM, FREQ. DEP. IMPEDANCE                  BUSHVER MARCH 20,1997 MSC.Nastran 1/23/97 PAGE 9
        SINGLE DOF , CRITICAL DAMPING, 3 EXCITATION FREQUENCIES
0
FREQUENCY =   1.100000E+00
       C O M P L E X     D I S P L A C E M E N T
       (REAL/IMAGINARY)

       POINT ID.      TYPE    T1      T2      T3      R1      R2      R3
0      11      G      .0      .0      .0      .0      .0      .0
                      .0      .0      .0      .0      .0      .0
0      12      G      -6.855670E-08  .0      .0      .0      .0      .0
                      -9.999999E-01  .0      .0      .0      .0      .0
1      VERIFICATION PROBLEM, FREQ. DEP. IMPEDANCE                  BUSHVER MARCH 20,1997 MSC.Nastran 1/23/97 PAGE 10
        SINGLE DOF , CRITICAL DAMPING, 3 EXCITATION FREQUENCIES
```

Результаты расчета сил для элемента CBUSH

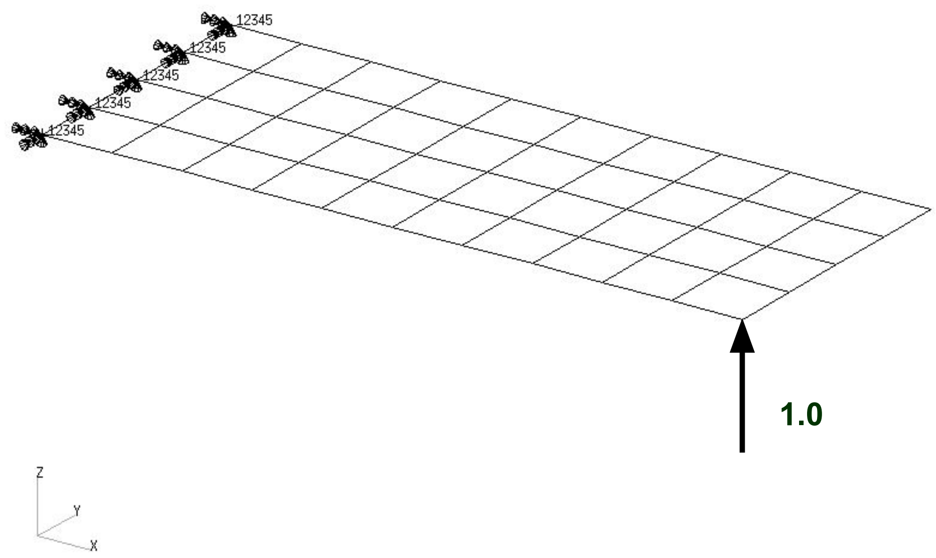
```
FREQUENCY =  9.000000E-01
       C O M P L E X    F O R C E S   I N   B U S H   E L E M E N T S   ( C B U S H )
       (REAL/IMAGINARY)

       ELEMENT-ID.    FORCE-X          FORCE-Y         FORCE-Z        MOWENT-X       MOMENT-Y       MOMENT-Z
0      1000     1.620000E+00   .0     .0      .0      .0      .0
              -8.100000E-01   .0     .0      .0      .0      .0
1      VERIFICATION PROBLEM, FREQ. DEP. IMPEDANCE                        BUSHVER MARCH 20,1997 MSC.Nastran 1/23/97 PAGE 11
        SINGLE DOF , CRITICAL DAMPING, 3 EXCITATION FREQUENCIES
0
FREQUENCY =  1.000000E+00
       C O M P L E X    F O R C E S   I N   B U S H   E L E M E N T S   ( C B U S H )
       (REAL/IMAGINARY)

       ELEMENT-ID.    FORCE-X          FORCE-Y         FORCE-Z        MOMENT-X       MOMENT-Y       MOMENT-Z
0      1000     2.000000E+00   .0     .0      .0      .0      .0
              -1.000000E+00   .0     .0      .0      .0      .0
1      VERIFICATION PROBLEM, FREQ. DEP. IMPEDANCE                        BUSHVER MARCH 20,1997 MSC.Nastran 1/23/97 PAGE 12
        SINGLE DOF , CRITICAL DAMPING, 3 EXCITATION FREQUENCIES
0
FREQUENCY =  1.100000E+00
       C O M P L E X    F O R C E S   I N   B U S H   E L E M E N T S   ( C B U S H )
       (REAL/IMAGINARY)

       ELEMENT-ID.    FORCE-X          FORCE-Y         FORCE-Z        MOMENT-X       MOMENT-Y       MOMENT-Z
0      1000     2.419999E+00   .0     .0      .0      .0      .0
              -1.210000E+00   .0     .0      .0      .0      .0
1      VERIFICATION PROBLEM, FREQ. DEP. IMPEDANCE                        BUSHVER MARCH 20,1997 MSC.Nastran 1/23/97 PAGE 13
        SINGLE DOF , CRITICAL DAMPING, 3 EXCITATION FREQUENCIES
0
```

Пример №5

Анализ частотного отклика прямым методом

Пример №5. Анализ частотного отклика прямым методом

- **Используя модель из Примера №1, прямым методом определите частотный отклик плоской пластины под действием гармонического возмущения – сосредоточенной силы, действующей на угол пластины. Определить решение с шагом 20 Гц в диапазоне 20 – 1000 Гц. Использовать конструкционное демпфирование g=0,06.**



Входной файл для Примера №5

```
ID SEMINAR, PROB5
SOL108
TIME30
CEND
TITLE = FREQUENCY RESPONSE DUE TO UNIT FORCE AT TIP
ECHO = UNSORTED
SPC = 1
SET 111 = 11, 33, 55
DISPLACEMENT(SORT2, PHASE) = 111
SUBCASE 1
DLOAD = 500
FREQUENCY = 100
$
OUTPUT (XYPLOT)
$
XTGRID= YES
YTGRID= YES
XBGRID= YES
YBGRID= YES
YTLOG= YES
YBLOG= NO
XTITLE= FREQUENCY (HZ)
YTTITLE= DISPLACEMENT RESPONSE AT LOADED CORNER, MAGNITUDE
YBTITLE= DISPLACEMENT RESPONSE AT LOADED CORNER, PHASE
XYPLOT DISP RESPONSE / 11 (T3RM, T3IP)
YTTITLE= DISPLACEMENT RESPONSE AT TIP CENTER, MAGNITUDE
YBTITLE= DISPLACEMENT RESPONSE AT TIP CENTER, PHASE
XYPLOT DISP RESPONSE / 33 (T3RM, T3IP)
YTTITLE= DISPLACEMENT RESPONSE AT OPPOSITE CORNER,
MAGNITUDE
YBTITLE= DISPLACEMENT RESPONSE AT OPPOSITE CORNER, PHASE
XYPLOT DISP RESPONSE / 55 (T3RM, T3IP)
$
```

```
BEGIN BULK
param,post,0
PARAM, COUPMASS, 1
PARAM, WTMASS, 0.00259
$
$ PLATE MODEL DESCRIBED IN NORMAL MODES
EXAMPLE
$
INCLUDE 'plate.bdf'
$
$ SPECIFY STRUCTURAL DAMPING
$
PARAM, G, 0.06
$
$ APPLY UNIT FORCE AT TIP POINT
$
RLOAD2, 500, 600, , ,310
$
DAREA, 600, 11, 3, 1.0
$
TABLED1, 310,
, 0., 1., 1000., 1., ENDT
$
$ SPECIFY FREQUENCY STEPS
$
FREQ1, 100, 20., 20., 49
$
ENDDATA
```

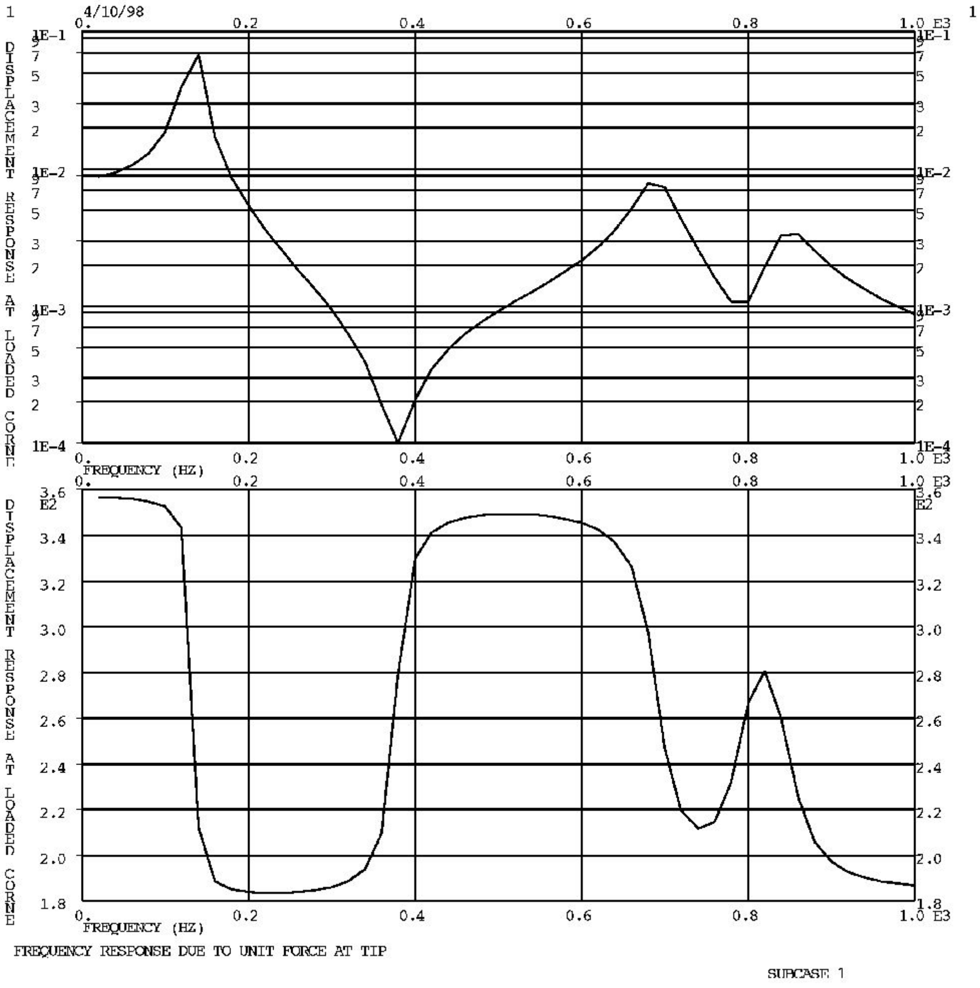
Результаты решения Примера №5

```
 POINT-ID =         11
                                             C O M P L E X   D I S P L A C E M E N T   V E C T O R
                                                                 (MAGNITUDE/PHASE)

      FREQUENCY    TYPE                   T1              T2              T3              R1              R2              R3
0   2.000000E+01     G                    .0              .0              8.817999E-03    6.435859E-04    2.632016E-03            .0
                                          .0              .0              356.4954        176.5664        176.5000                .0
0   4.000000E+01     G                    .0              .0              9.404316E-03    6.434992E-04    2.795561E-03            .0
                                          .0              .0              356.2596        176.5677        176.2785                .0
                                                         .
                                                         .
                                                         .
0   9.799999E+02     G            .0              .0              9.965085E-04    2.691742E-04    4.097779E-04            .0
                                  .0              .0              187.6832        7.8008          15.1581                 .0
0   1.000000E+03     G            .0              .0              8.803169E-04    2.354655E-04    3.317750E-04            .0
                                  .0              .0              186.9298        8.2146          14.6645                 .0
                                                         .
                                                         .
                                                         .
      POINT-ID =         33
                                             C O M P L E X   D I S P L A C E M E N T   V E C T O R
                                                                 (MAGNITUDE/PHASE)

      FREQUENCY    TYPE                   T1              T2              T3              R1              R2              R3
0   2.000000E+01     G            .0              .0              8.183126E-03    5.993296E-04    2.443290E-03            .0
                                  .0              .0              356.4899        176.5639        176.4950                .0
0   4.000000E+01     G            .0              .0              8.768992E-03    6.006201E-04    2.606561E-03            .0
                                  .0              .0              356.2376        176.5565        176.2581                .0
                                                         .
                                                         .
                                                         .

0   9.799999E+02     G            .0              .0              6.867234E-04    3.836353E-04    5.393046E-04            .0
                                  .0              .0              188.0180                5.5597          10.0794                 .0
0   1.000000E+03     G            .0              .0              6.062436E-04    3.454143E-04    4.648783E-04            .0
                                  .0              .0              186.8358                5.4959          8.8514                  .0
                                                         .
                                                         .
                                                         .
```

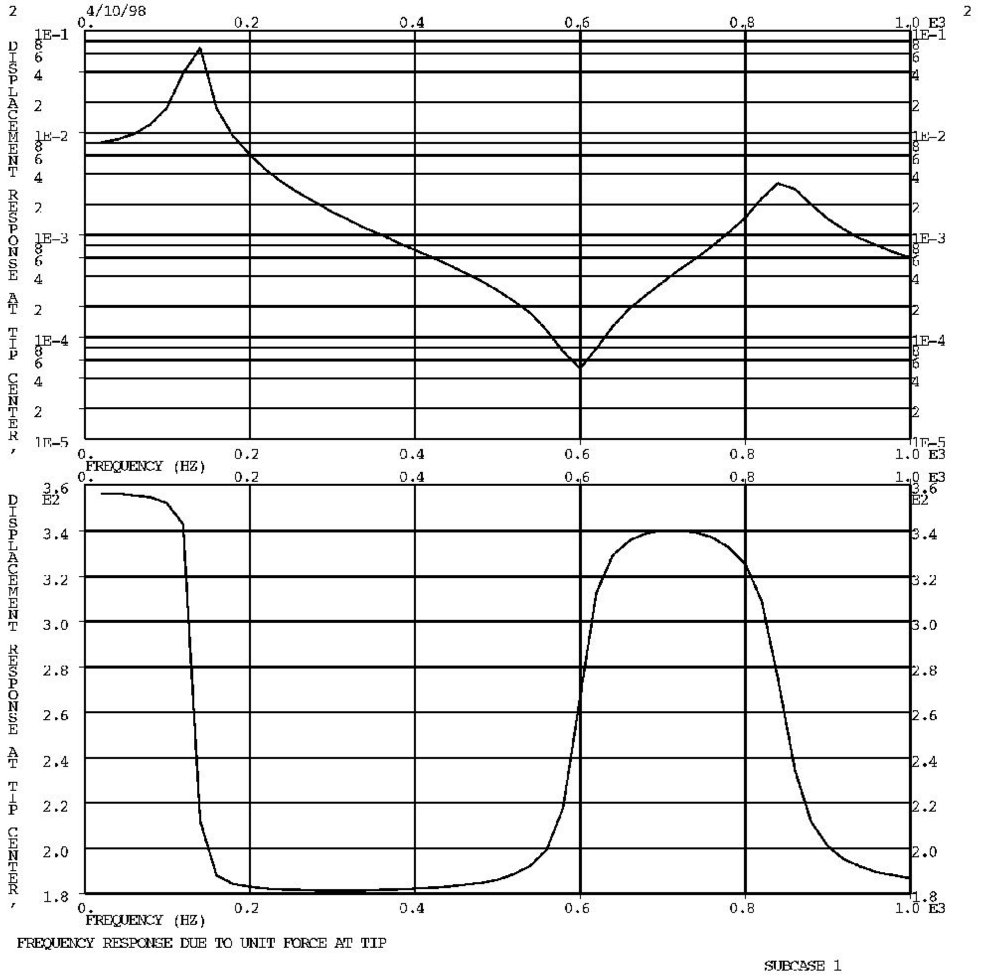
Результаты решения Примера №5

```
1    FREQUENCY RESPONSE DUE TO UNIT FORCE AT TIP                                 APRIL   8, 1998  MSC.Nastran  4/ 6/98   PAGE    17
0                                                                                                  SUBCASE 1
0                              X Y - O U T P U T  S U M M A R Y  ( R E S P O N S E )
0 SUBCASE  CURVE FRAME                           XMIN-FRAME/    XMAX-FRAME/    YMIN-FRAME/      X FOR         YMAX-FRAME/      X FOR
     ID     TYPE    NO.     CURVE ID.              ALL DATA       ALL DATA       ALL DATA        YMIN           ALL DATA        YMAX
0       1  DISP      1        11(  5,--)     2.000000E+01   1.000000E+03   1.001178E-04   3.800000E+02   6.794556E-02   1.400000E+02
                                             2.000000E+01   1.000000E+03   1.001178E-04   3.800000E+02   6.794556E-02   1.400000E+02
0       1  DISP      1        11(--, 11)     2.000000E+01   1.000000E+03   1.834655E+02   2.200000E+02   3.564954E+02   2.000000E+01
                                             2.000000E+01   1.000000E+03   1.834655E+02   2.200000E+02   3.564954E+02   2.000000E+01
0       1  DISP      2        33(  5,--)     2.000000E+01   1.000000E+03   4.981586E-05   6.000000E+02   6.858238E-02   1.400000E+02
                                             2.000000E+01   1.000000E+03   4.981586E-05   6.000000E+02   6.858238E-02   1.400000E+02
0       1  DISP      2        33(--, 11)     2.000000E+01   1.000000E+03   1.815143E+02   3.000000E+02   3.564899E+02   2.000000E+01
                                             2.000000E+01   1.000000E+03   1.815143E+02   3.000000E+02   3.564899E+02   2.000000E+01
0       1  DISP      3        55(  5,--)     2.000000E+01   1.000000E+03   2.144667E-04   1.000000E+03   6.896591E-02   1.400000E+02
                                             2.000000E+01   1.000000E+03   2.144667E-04   1.000000E+03   6.896591E-02   1.400000E+02
0       1  DISP      3        55(--, 11)     2.000000E+01   1.000000E+03   6.565820E+00   7.599999E+02   3.580194E+02   7.800000E+02
                                             2.000000E+01   1.000000E+03   6.565820E+00   7.599999E+02   3.580194E+02   7.800000E+02
```

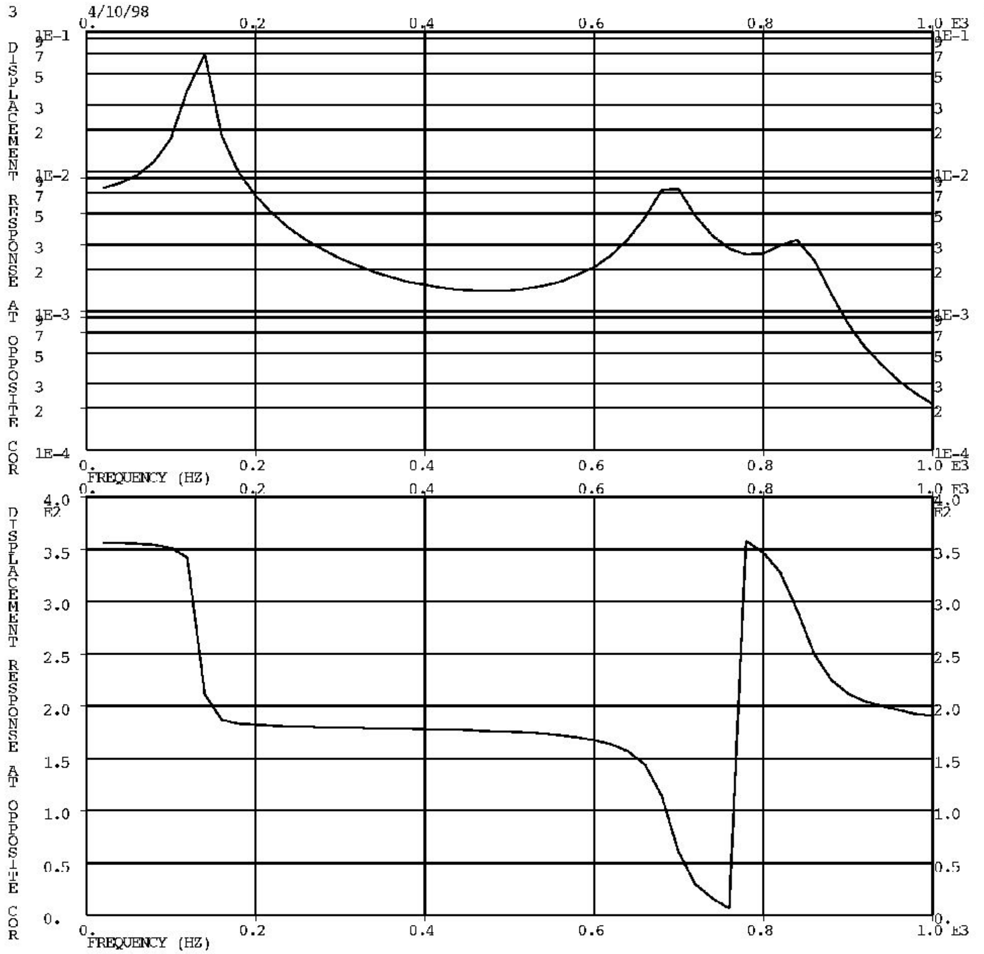
Результаты решения Примера №5



Результаты решения Примера №5



Результаты решения Примера №5



FREQUENCY RESPONSE DUE TO UNIT FORCE AT TIP

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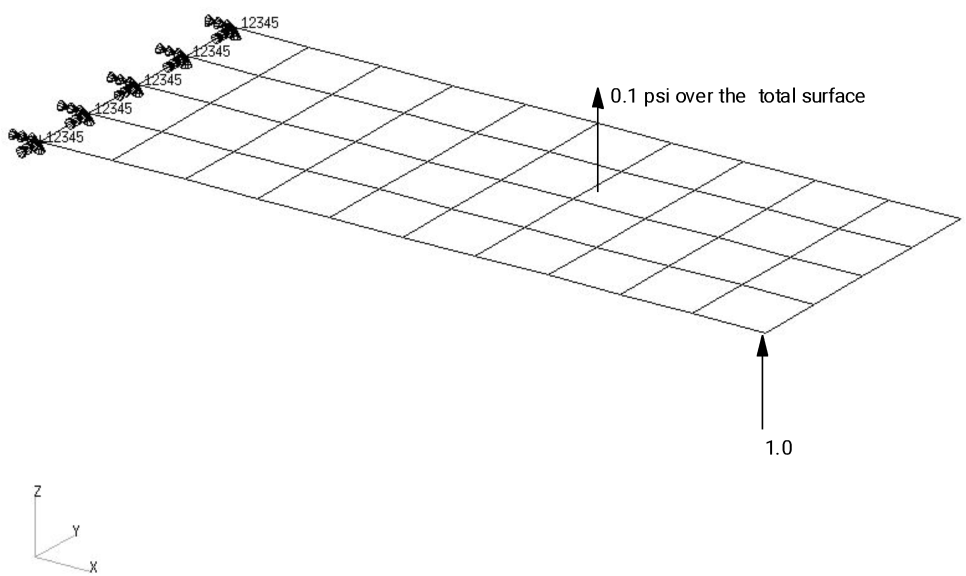
Пример №6

Анализ частотного отклика модальным методом

Пример №6. Анализ частотного отклика модальным методом

- **Используя модель из Примера №1, модальным методом определите частотный отклик плоской пластины под действием гармонического возмущения – давления в 0,1 фунт/кв. дюйм и сосредоточенной силы в 1 фунт, приложенной к углу пластины и запаздывающей по фазе на 45°. Использовать модальное демпфирование ζ = 0,03. Определить решение с шагом 20 Гц в диапазоне 20 – 1000 Гц, а также на пяти частотах в диапазоне половинной мощности вблизи каждой резонансной частоты конструкции.**



Входной файл для Примера №6

```
ID SEMINAR, PROB6
SOL 111
TIME30
CEND
TITLE = FREQUENCY RESPONSE WITH PRESSURE AND POINT LOADS
ECHO = UNSORTED
SEALL = ALL
SPC = 1
SET 111 = 11, 33, 55
DISPLACEMENT(PHASE, PLOT) = 111
METHOD = 100
FREQUENCY = 100
SDAMPING = 100
SUBCASE 1
DLOAD = 100
LOADSET = 100
$
OUTPUT (XYPLOT)
$
XTGRID= YES
YTGRID= YES
XBGRID= YES
YBGRID= YES
YTLOG= YES
YBLOG= NO
XTITLE= FREQUENCY (HZ)
YTTITLE= DISPLACEMENT RESPONSE AT LOADED CORNER, MAGNITUDE
YBTITLE= DISPLACEMENT RESPONSE AT LOADED CORNER, PHASE
XYPLOT DISP RESPONSE / 11 (T3RM, T3IP)
YTTITLE= DISPLACEMENT RESPONSE AT TIP CENTER, MAGNITUDE
YBTITLE= DISPLACEMENT RESPONSE AT TIP CENTER, PHASE
XYPLOT DISP RESPONSE / 33 (T3RM, T3IP)
YTTITLE= DISPLACEMENT RESPONSE AT OPPOSITE CORNER,
MAGNITUDE
YBTITLE= DISPLACEMENT RESPONSE AT OPPOSITE CORNER, PHASE
XYPLOT DISP RESPONSE / 55 (T3RM, T3IP)
$
BEGIN BULK
PARAM, COUPMASS, 1
PARAM, WTMASS, 0.00259
$
$ PARAMETERS FOR POST-PROCESSING
$
$ PLATE MODEL DESCRIBED IN NORMAL MODES EXAMPLE
$
INCLUDE 'plate.bdf'
$
$ EIGENVALUE EXTRACTION PARAMETERS
$
EIGRL, 100, 10., 2000.
$
$ SPECIFY MODAL DAMPING
$
TABDMP1, 100, CRIT,
+, 0., .03, 10., .03, ENDT
$
$ APPLY UNIT PRESSURE LOAD TO THE PLATE
$
LSEQ, 100, 300, 400
$
PLOAD2, 400, 1., 1, THRU, 40
$
$ APPLY PRESSURE LOAD
$
```

Входной файл для Примера №6

```
RLOAD2, 400, 300, , ,310
$
TABLED1, 310,
, 10., 1., 1000., 1., ENDT
$
$ POINT LOAD
$
$ IF 'DAREA' CARDS ARE REFERENCED,
$ 'DPHASE' AND 'DELAY' CAN BE USED
$
RLOAD2, 500, 600, , 320,310
$
DPHASE, 320, 11, 3, -45.
$
$
DAREA, 600, 11, 3, 1.0
$
$ COMBINE LOADS
$
DLOAD, 100, 1., .1, 400, 1.0, 500
$
$
$ SPECIFY FREQUENCY STEPS
$
FREQ1, 100, 20., 20., 49
FREQ4, 100, 20., 1000., .03, 5
$
ENDDATA
```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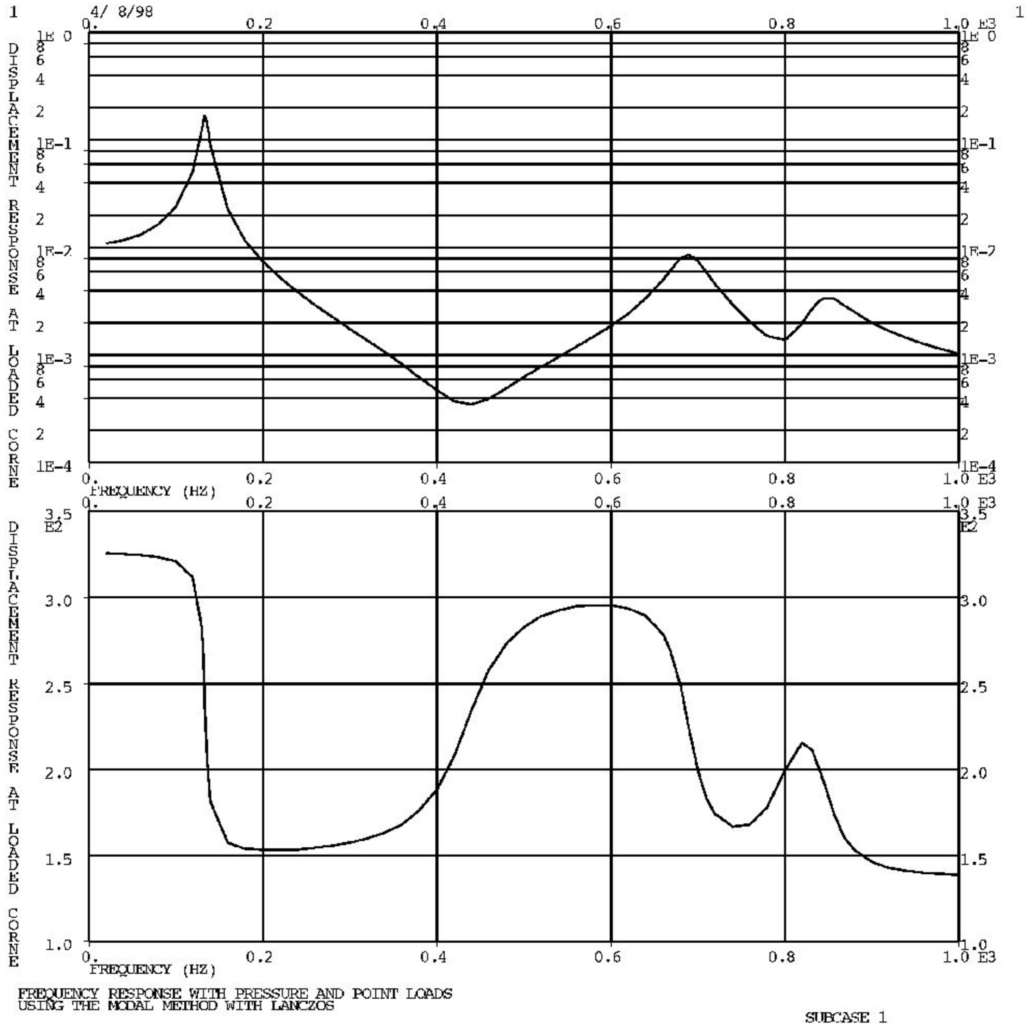
Результаты решения Примера №6

0 SUBCASE 1

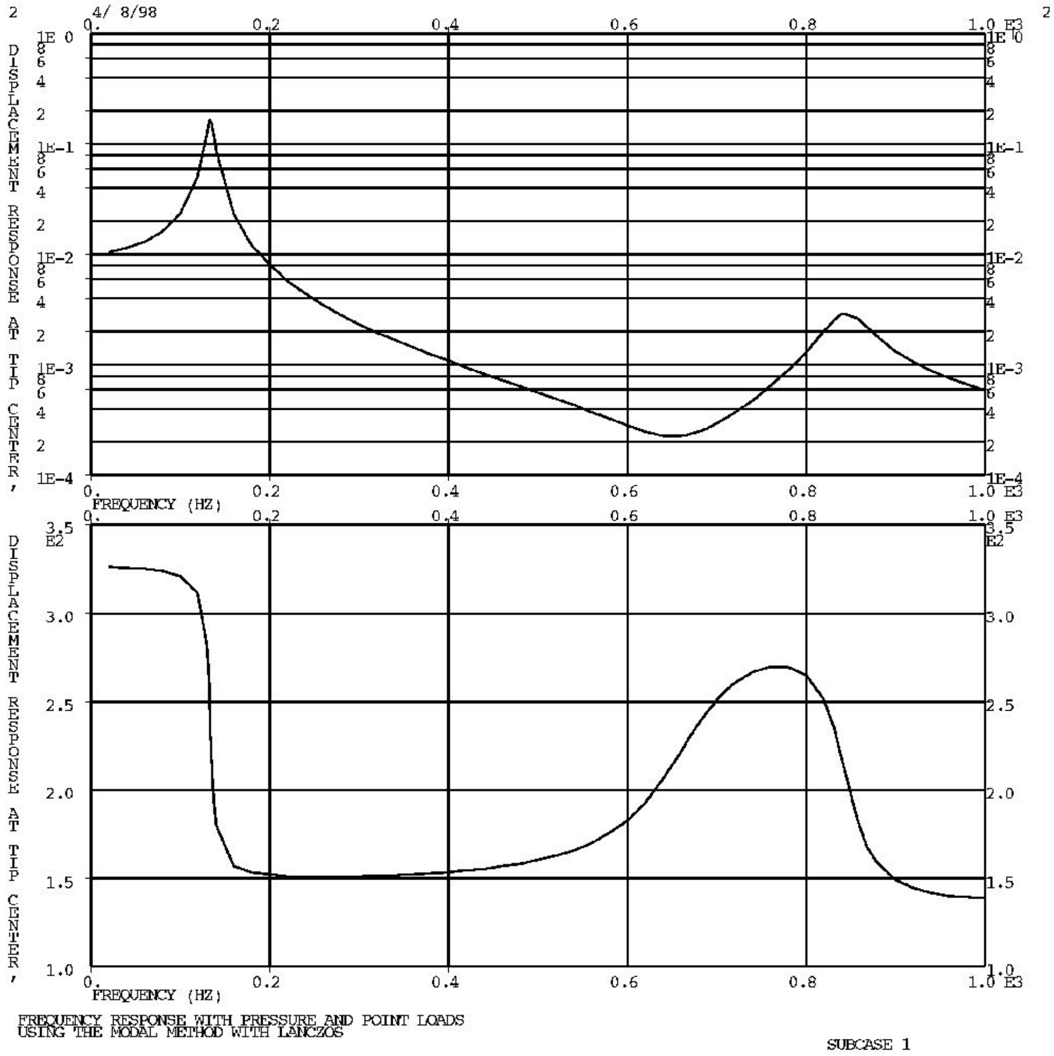
0 X Y - O U T P U T S U M M A R Y (R E S P O N S E)

0	SUBCASE ID	CURVE TYPE	FRAME NO.	CURVE ID.	XMIN-FRAME/ ALL DATA	XMAX-FRAME/ ALL DATA	YMIN-FRAME/ ALL DATA	X FOR YMIN	YMAX-FRAME/ ALL DATA	X FOR YMAX
0	1	DISP	1	11(5,--)	2.000000E+01	1.000000E+03	3.481835E-04	4.400000E+02	1.699121E-01	1.336996E+02
					2.000000E+01	1.000000E+03	3.481835E-04	4.400000E+02	1.699121E-01	1.336996E+02
0	1	DISP	1	11(--, 11)	2.000000E+01	1.000000E+03	1.390213E+02	1.000000E+03	3.258276E+02	2.000000E+01
					2.000000E+01	1.000000E+03	1.390213E+02	1.000000E+03	3.258276E+02	2.000000E+01
0	1	DISP	2	33(5,--)	2.000000E+01	1.000000E+03	2.271459E-04	6.600000E+02	1.700317E-01	1.336996E+02
					2.000000E+01	1.000000E+03	2.271459E-04	6.600000E+02	1.700317E-01	1.336996E+02
0	1	DISP	2	33(--, 11)	2.000000E+01	1.000000E+03	1.385571E+02	1.000000E+03	3.263339E+02	2.000000E+01
					2.000000E+01	1.000000E+03	1.385571E+02	1.000000E+03	3.263339E+02	2.000000E+01
0	1	DISP	3	55(5,--)	2.000000E+01	1.000000E+03	1.278678E-04	1.000000E+03	1.696787E-01	1.336996E+02
					2.000000E+01	1.000000E+03	1.278678E-04	1.000000E+03	1.696787E-01	1.336996E+02
0	1	DISP	3	55(--, 11)	2.000000E+01	1.000000E+03	1.687413E+01	7.001384E+02	3.573561E+02	7.104853E+02
					2.000000E+01	1.000000E+03	1.687413E+01	7.001384E+02	3.573561E+02	7.104853E+02

Результаты решения Примера №6



Результаты решения Примера №6



Результаты решения Примера №6