

Test Paper of Wuhan University of Technology (A)

2018-2019 Academic Year 1st Semester, Course: _____,

Closed-book Exam

Time: 120mins, Class hours: _____ Credits: _____ Total Points: 100, Percent in final evaluation

result: _____ % Date: _____

No.	一 I	二 II	三 III	四 IV	五 V	六 VI	七 VII	八 VIII	九 IX	十 X	合计 Total	Teacher
Full score											100	
Score	8	15	14	27	8						72	

得分 Score	8
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I. Single-choice questions (2 points * 5=10 points)

1. (A) The basic characteristics of elastic elements are
- A. the elements that represent the relationship between force and displacement
 - B. the elements that represent the relationship between force and speed
 - C. the elements that represent the relationship between force and acceleration
 - D. the elements that represent the relationship between displacement and speed
2. (A) For the forced vibration under the simple harmonic excitation of the single-degree-of-freedom system, the magnitude of the response amplitude in the low-frequency zone, resonance zone and high-frequency zone mainly depends the system's
- A. spring stiffness, damping and inertia
 - B. damping, spring stiffness and inertia
 - C. inertia, spring stiffness and damping
 - D. inertia, damping and spring stiffness

3. (B) The function that best reflects the correlation of random variables at different times in different random processes is

- A. autocorrelation function
- B. cross-correlation function
- C. auto-spectrum
- D. frequency response function

4. (C) There are mainly three kinds of vibration problems. Besides vibration analysis and prediction of vibration environment, what is the other vibration problem?

- A. vibration prediction
- B. vibration modeling
- C. system identification
- D. modal analysis

5. (B) The function that cannot reflect the inherent characteristics of the system is

- A. autocorrelation function
- B. impulse response function
- C. frequency response function
- D. natural frequency

得分 Score	15
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II. Explanation of phases (5 points * 5=25 points)

6. Sample function

Solution: 由函数由任意时刻,

在无数多个函数,在任意时刻进行采样,得到样本函数。
样本函数代表了被取样函数的部分特性。

7. Multi-degree-of-freedom vibration system

Solution: 由多个坐标决定系统位置的系^{振动}统。

为求至

8. Power spectrum

Solution: 功率谱, 是描述振动系统振动作功的频谱或谐波.

9. Spectral analysis

Solution: 分析谐波频谱的振幅比叫做频谱分析.

10. Principle of dynamic vibration absorber

Solution: 动力吸振器不是能量削减, 而是在振动系统中加入一个副质量, 在振动过程中与主质量振动相位相反, 从而达到能量抵消, 减弱振动的效果.

得分
Score

14

III. Short-answer questions (10 points * 2 = 20 points)

11. Give examples to illustrate the similarities and differences between active vibration isolation and passive vibration isolation.

Solution: 区别: ①主动隔振的振源来自机器本身, 被动隔振时, 振源来自支架或地面. ②主动隔振常用于工厂中的重载机械, 或各型车辆发动机; 被动隔振主要用于精密机械或测量仪器, 避免人为误差.

相同: ①都是通过弹簧元件或阻尼器元件来达到隔振效果. ②都是频率比越小, 振动越小, 隔振效果越好. ③主动与被动隔振都要在设计时计算隔振系数与位移传递率, 进行设备验算.

12. What are the concepts of impulse response function and frequency response function and their relationship? Solution: 概念: 频率响应函数是由激励频率与系统特性共同作用.

概念: 脉冲响应函数是由δ函数为系统外部环境, 即狄拉克函数形式的脉冲为振源与系统特性共同作用.

$$\text{二者的关系: } Y(\omega) = H(\omega)X(\omega)$$

得分
Score

27

IV. Calculation (10 points * 3 questions = 30 points)

13. The probability density function of random variable X is $p(x) = ae^{-b|x|}$, of which a and b are constants. Find the relationship between a and b , and when $a = 1$, determine the distribution function $F(x)$. Solution: (1)

$$\int_{-\infty}^{+\infty} p(x) dx = 1$$

$$\int_{-\infty}^0 ae^{bx} + \int_0^{+\infty} ae^{-bx} = 2 \int_0^{+\infty} ae^{-bx} = -\frac{2a}{b} e^{-bx} \Big|_0^{+\infty} = 1$$

$$\text{then: } b = -2a$$

$$(2) \quad a = 1, \quad b = -2.$$

$$\text{so } p(x) = e^{-2|x|}$$

$F(x)$

$$\text{当 } x < 0 \text{ 时, } F(x) = \int_{-\infty}^x e^{-2|x|} dx = -\frac{1}{2} e^{-2x}$$

$$\text{当 } x \geq 0 \text{ 时,}$$

$$F(x) = \int_{-\infty}^0 e^{-2|x|} dx + \int_0^x e^{-2|x|} dx = 1 + \frac{1}{2} e^{-2x}.$$

$$F(x) = \begin{cases} -\frac{1}{2} e^{-2x} & x < 0 \\ \frac{3}{2} & x = 0 \\ 1 + \frac{1}{2} e^{-2x} & x > 0 \end{cases}$$

14. It is already known that $R(x) = 25e^{-4|t|} \cos \omega t + 16$, work out $\mu(x)$, σ_x^2 , $S_x(\omega)$.

Solution: $N(x) = R(x)_{t \rightarrow \infty} = 16 = \frac{25}{2} \left[\int_{-\infty}^0 e^{4t} (1 + e^{-2\omega t}) + \int_0^{\infty} e^{-4t} (1 + e^{-2\omega t}) \right]$

$N(x) = \sqrt{N(x)^2} = 4$.

$E(x^2) = R(x)_{t \rightarrow 0} = 25 + 16 = 41$

$\sigma_x^2 = E(x^2) - N(x)^2 = 41 - 16 = 25$

$S_x(\omega) = \int_{-\infty}^{\infty} R(\tau) e^{-i\omega\tau} d\tau$
 $= \int_{-\infty}^0 25e^{4\tau} (1 + e^{-2i\omega\tau}) + \int_0^{\infty} 25e^{-4\tau} (1 + e^{-2i\omega\tau}) d\tau$
 $= 25 \left[\int_{-\infty}^0 e^{4\tau} (1 + e^{-2i\omega\tau}) + \int_0^{\infty} e^{-4\tau} (1 + e^{-2i\omega\tau}) d\tau \right]$

15. Take the linear displacement of m_2 as the coordinates of motion to determine the equivalent stiffness k_B and equivalent mass m_B of the system and natural frequency of vibration. Each value in the figure is known, regardless of the mass of the horizontal lever and the distributed mass of the elastic element.

Solution 设 m_2 向下位移 x

$U_a = \frac{1}{2} k_1 \left(\frac{a_2 x}{a_4} \right)^2 + \frac{1}{2} k_2 \left(\frac{a_3 x}{a_4} \right)^2$

$U_e = \frac{1}{2} k_B x^2$

$U_a = U_e$

then $k_B = \frac{a_2^2 k_1 + a_3^2 k_2}{a_4^2}$

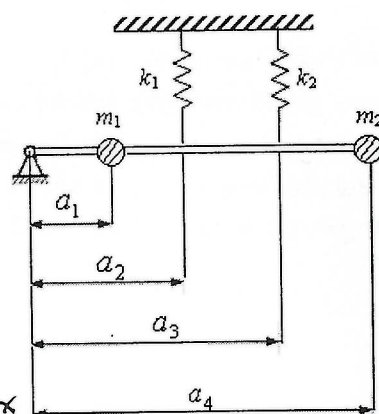
$M_a = m_1 \frac{a_1 \ddot{x}}{a_4} + m_2 \ddot{x} - k_1 \frac{a_2 x}{a_4} - k_2 \frac{a_3 x}{a_4}$

$M_B = m_B \ddot{x}$

$M_a = M_B$
 $m_B \ddot{x} = m_1 \frac{a_1^2 \ddot{x}}{a_4} + m_2 \ddot{x} - k_1 \frac{a_2^2 x}{a_4} - k_2 \frac{a_3^2 x}{a_4}$

then $\frac{1}{m_B} = \frac{m_1 \frac{a_1^2}{a_4} + m_2 - k_1 \frac{a_2^2}{a_4} - k_2 \frac{a_3^2}{a_4}}{a_4^2}$

then $f = \frac{P}{2\pi} = \frac{1}{2\pi} \sqrt{\frac{k_B}{m_B}} = \frac{1}{2\pi} \sqrt{\frac{\ddot{x} a_2^2 k_1 + \ddot{x} a_3^2 k_2}{m_1 \frac{a_1^2 \ddot{x}}{a_4} + m_2 \ddot{x} - k_1 \frac{a_2^2 x}{a_4} - k_2 \frac{a_3^2 x}{a_4}}}$



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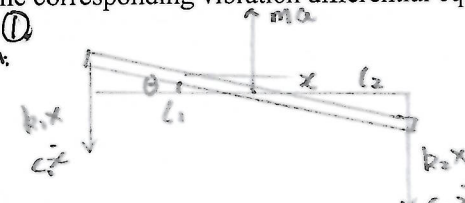
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得分 8 V. Comprehensive problem-solving questions (15 points)

16. There are two methods to simplify the car into a two-degree-of-freedom vibration system model in the course. Draw the diagrams of two-degree-of-freedom vibration system models under the two methods; write down their respective assumptions for simplification and explain the physical meaning of each value in the diagrams. If you want to analyze the deformation and dynamic load of suspension and tire under irregular road (displacement) excitation, which two-degree-of-freedom model is best used? Deduce the corresponding vibration differential equation of this model.

Solution ①

(1)



$$\begin{cases} m\ddot{x} = -k_1(x + \theta l_1) - k_2(x - \theta l_2) \\ J\ddot{\theta} = -C_1 \dot{x} l_1 - C_2 \dot{x} l_2 \end{cases}$$

(3) 最好采用①方案自由度模型.

Solution: m 为质量, a 加速度

(2)

- k_1 前桥弹簧刚度
- k_2 后桥弹簧刚度
- θ : 车桥俯仰角
- l_1 前桥与车桥中心距
- l_2 后桥与车桥中心距
- x : 弹簧变形长度
- C_1 : 前桥阻尼系数
- C_2 : 后桥阻尼系数
- $\dot{x}$: 弹簧变形速度