Control of Mechatronic Systems

Study programme: N0714A270012 Control of Machines and Processes
Academic year: 2023/2024

1. Modeling of mechatronic systems (kinematics and dynamics of mechanisms and their simulation). Utilization in Hardware in the Loop Simulation technology.
2. Software support for mechatronic system simulation and control (CAD, simulation programs, verification of control algorithms).
3. Control systems for mechatronics and their integration into hierarchical control systems. Reliability and safety of control systems. Intensity of disturbances and mean time between disturbances. Types of dependence of the intensity of faults on the time of operation. Bathtub curve.
4. A/D and D/A converters, quantization noise, signal-to-noise ratio. Frequency measurement range, Shannon-Kotelnik sampling theorem and aliasing in spectra. Nyquist frequency. Anti-aliasing filter. The principle of double integration converters, stepwise approximation, sigma-delta converters and flash converters.
5. Analog and digital frequency filters. Type and parameters of filters, pass and stop band, transition band, ripple in the pass and stop band. What is the difference between FIR and IIR filters? What is the meaning of the linear dependence of the filter transfer phase on frequency.
6. Microprocessors, single-board computers, single-chip processors, and signal processors. Architecture, properties, programming. IPC and PLC control computers. Application areas.
7. Industrial buses for the transfer of digital data between sensors, actuators and control systems (CAN, Profibus).
8. Basic circuit elements for power electronics (power diodes, thyristors, triacs) and their volt-ampere characteristics. Controlled rectifiers and frequency converters. Transistor in switching mode.
9. Electric actuators, basic division of electric motors into AC, DC, stepper, linear and piezo actuators. Harmonic gearbox and ball screw function. Control circuit for position control.
10. DC electric motors, excitation types, importance of commutator. Characteristics (dependence of torque on speed), speed control method and area of use.
11. AC electric motors – synchronous and asynchronous (ring and with short-circuit armature). Characteristics (dependence of torque on speed), speed control method using frequency converters and area of application.
12. Stepper motors. Principle of operation. Rotor design. Rotation control method and application area.
13. Hydraulic actuators. The basic structure of the hydraulic circuit – hydrogen generators, distributors and hydraulic motors.
14. Properties and management of hydraulic drives, circuit types. Manifolds, control valves for continuous flow control, proportional valves and servo valves. Servomechanisms. Position, speed, pressure and force control.
15. Control of pneumatic drives, distributors, valve terminals, continuous control of pneumatic drive. Pneumatic actuators. Basic structure of the pneumatic circuit – compressors, distributors and pneumatic motors. Describe the principle of a nozzle, flap.

16. Fourier transform (FT) direct and inverse, properties of the transform (symmetry of the components with respect to the Nyquist frequency). The degree of acceleration of the FT calculation by the FFT method. Use of FFT for filtering in the frequency domain (calculation of the spectrum, its subsequent adjustment and calculation of the inverse FFT). Spectrum scales (linear, logarithmic and dB, RMS, PSD and PWR). Reciprocal conversion between root mean square (RMS), power (PWR) and power spectral density (PSD) for a frequency spectrum.
17. Analytical signal (Hilbert transform (HT)), signal modulation and demodulation (envelope, phase and its unwrapping algorithm). How HT changes the phase of the harmonic signal. Calculation of HT using FFT and digital filter. Application for calculation of envelope and phase (measurement of angular oscillations).
18. Averaging the spectra and time records. Optimal block overlap when calculating averaged spectra. Meaning of time windows and their types (Rectangular, Hanning and Flat Top). Which time window is used for AC calibration?
19. Measurement of frequency characteristics of mechanical systems using FFT and evaluation of their accuracy using the coherence function. Random vibrator excitation and impulse hammer excitation for modal analysis. Use of operational waveforms and modal analysis to diagnose and determine the dynamic properties of machines.
20. Order analysis of vibrations and noise of rotating machines. Measurement of the basic impulse signal (tacho signal) for calculating machine revolutions. Sample rate control that is directly proportional to RPM. Upsampling the signal to a constant number of samples per revolution. Manifestation of unbalance and establishment of machines according to the occurrence of spectrum components with low multiples of the machine's rotation frequency. Applications in machine diagnostics.
21. Static and dynamic balancing of rotors. Balancing in one and two planes. Specific unbalance and its dependence on speed. Balance criteria (Grade). Balancing procedure in one plane. Diagnostics of gearboxes with gears. Calculation of the engagement frequency, harmonics and side components in the frequency spectrum.
22. Special sensors for measuring dynamic force, torque, vibration (displacement, velocity and acceleration), yaw rate (electronic gyroscopes) and noise (acoustic pressure and noise intensity). What is acoustic emission? Charge amplifiers, sensors with connection via CCLD (IEPE) to power the sensor preamplifiers. RPM measurement for diagnostics, tacho signal evaluation.
23. Decibels for noise and vibration. CPB analyzers with bandpass filters. The relationship between the center frequency and the width of the 1/n-octave frequency band. Use of 1/1 and 1/3-octave analyzer in the field of influence of vibrations on the human organism. Evaluation of the root mean square value (RMS) of the signals from the measured data. How is RMS calculated from a sine signal?
24. Quality control of rolling bearings in production and diagnostics of rolling bearings in machine operation. Advantages of the signal envelope method. Diagnostics of sliding bearings of large rotor systems (orbits), proximity probes. How are shaft movements measured in a plain bearing? Full and single-sided frequency spectrum. Self-excited rotor oscillations (whirle and whip), critical rotor speeds.
25. Testing of products for resistance against mechanical stress. Resonant and random loading for product life tests. Cam, electrodynamic and electrohydraulic loading machines. Load spectra. Degree of damage.