CAPITAL UNIVERSITY

SUBJECT: ADVANCED CONTROL SYSTEM

B TECH ELECTRICAL & ELECTRONICS ENGINEERING

1. Explain the principle of duality between controllability and observability.

Ans- The concepts of controllability and observability are very similar. In fact, there is a concrete relationship between the two. We can say that a system (A, B) is controllable if and only if the system (A', C, B', D) is observable. This fact can be proven by plugging A' in for A, and B' in for C into the observability Gramian. The resulting equation will exactly mirror the formula for the controllability Gramian, implying that the two results are the same.

2. Explain the stability in the sense of Lyapunov.

Ans- Lyapunov stability of an equilibrium means that solutions starting "close enough" to the equilibrium (within a distance from it) remain "close enough" forever (within a distance from it). Note that this must be true for *any* that one may want to choose.

3. Discuss the basic concept of describing function methods.

Ans- Describing Function (DF) is a classical tool for analyzing the existence of limit cycles in nonlinear systems based in the frequency-domain approach. Although this method is not as general as the analysis for linear system is, it gives good approximated results for relay feedback systems.

4. Explain the classification of non-linearities and give the examples for each.

Ans-

1. Geometric Nonlinearity:

The changing geometric configuration due to large deformation of the structure cause nonlinear behavior. Geometric nonlinearity is not only because of large deformation but also due to large strain & large rotation too. The geometric nonlinearity causes to change in geometry cross section due to large deformation. Geometry buckling is also cause of geometric non linearity, in case of buckling huge compressive load causes the structural member to buckle resulting higher displacement. Buckling is a good example of geometric nonlinearity.

2. Material Nonlinearity:

In real world all engineering material are inherently nonlinear but we can idealize by accounting only certain effect which are important for analysis. The linear materials is most simplified material type. The other type is nonlinear elastic if the deformation is recoverable and plastic if deformation is permanent. Examples of nonlinear material models are large strain (Visco) elastic-plasticity and hyper-elasticity (rubber and plastic materials).

3. Contact Nonlinearity:

In contact nonlinearity abrupt change in stiffness may occur when bodies come into or out of contact each other. This type on nonlinearity is used to simulate the gap between two parts. While defining contact between two bodies, you need to decide whether it carries the friction or not. Friction coefficient can be used to decide the amount of resistance between the contact bodies. The selection of friction coefficient affects the contacting surfaces behavior and hence the friction coefficient is selected based on dry or lubricated friction, contacting material, etc. Sometimes boundary conditions can also be treated as nonlinear analysis like elastic support.

Few examples are: when say a round object falls on an elastic deformable surface, gear teeth, a cylindrical object rolls over a surface.

5.. Explain the effect of state feedback on controllability and observability.

Ans- An essential system property in state feedback is Controllability, and our first important observation is that Controllability is invariant with respect to state feedback. It is interesting to note that, on the other hand, Observability is not invariant with respect to feedback.

6. List out the common physical non-linearities with an example.

Ans- There are some nonlinearities that happen so frequently in physical systems that they are called "Common nonlinearities". These common nonlinearities include Hysteresis, Backlash, and Dead-zone.

Hysteresis

Continuing with the example of a household thermostat, let's say that your thermostat is set at 70 degrees (Fahrenheit). The furnace turns on, and the house heats up to 70 degrees, and then the thermostat dutifully turns the furnace off again. However, there is still a large amount of residual heat left in the ducts, and the hot air from the vents on the ground may not all have risen up to the level of the thermostat. This means that after the furnace turns off, the house may continue to get hotter, maybe even to uncomfortable levels.

So, the furnace turns off, the house heats up to 80 degrees, and then the air conditioner turns on. The temperature of the house cools down to 70 degrees again, and the A/C turns back off. However, the house continues to cool down, and then it gets too cold, and the furnace needs to turn back on.

As we can see from this example, a bang-bang controller, if poorly designed, can cause big problems, and it can waste lots of energy. To avoid this, we implement the idea of Hysteresis, which is a set of threshold values that allow for overflow outputs. Implementing hysteresis, our furnace now turns off when we get to 65 degrees, and the house slowly warms up to 75 degrees, and doesn't turn on the A/C unit. This is a far preferable solution.

Backlash

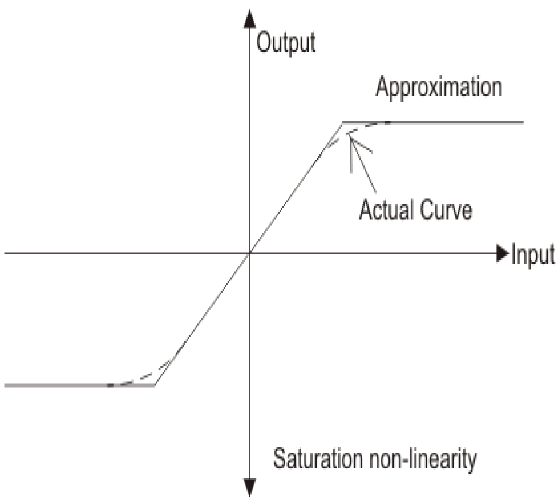
E.g.: Mechanical gear.

Dead-Zone

A dead-zone is a kind of non-linearity in which the system doesn't respond to the given input until the input reaches a particular level or it can refer to a condition in which output becomes zero when the input crosses certain limiting value. Dead zone nonlinearity is shown in various electrical devices like motors, DC servo motors, actuators etc.

7. Describe the saturation and backlash non-linearities.

Ans- **Saturation nonlinearity** is a common type of nonlinearity. For example, see this nonlinearity in the saturation in the magnetizing curve of dc-motor. In order to understand this type of nonlinearity let us discuss saturation curve or magnetizing curve which is given below:



From the above curve we can see that the output showing linear behavior in the beginning but after that there is a saturation in the curve which one kind of non-linearity in the system. We have also shown approximated curve. Same type of saturation non linearity also we can see in an amplifier for which the output is proportional to the input only for a limited range of values of input. When the input exceeds this range, the output tends to become non linearity.

Another important nonlinearity commonly occurring in the physical system is hysteresis in mechanical transmissions such as gear trains and linkages. This nonlinearity is somewhat different from magnetic hysteresis and is commonly referred to as **backlash nonlinearities**. Backlash in fact is the play between the teeth of the drive gear and those of the driven gear. Consider a gearbox as shown in below figure (a) having backlash as illustrated in fig (b).

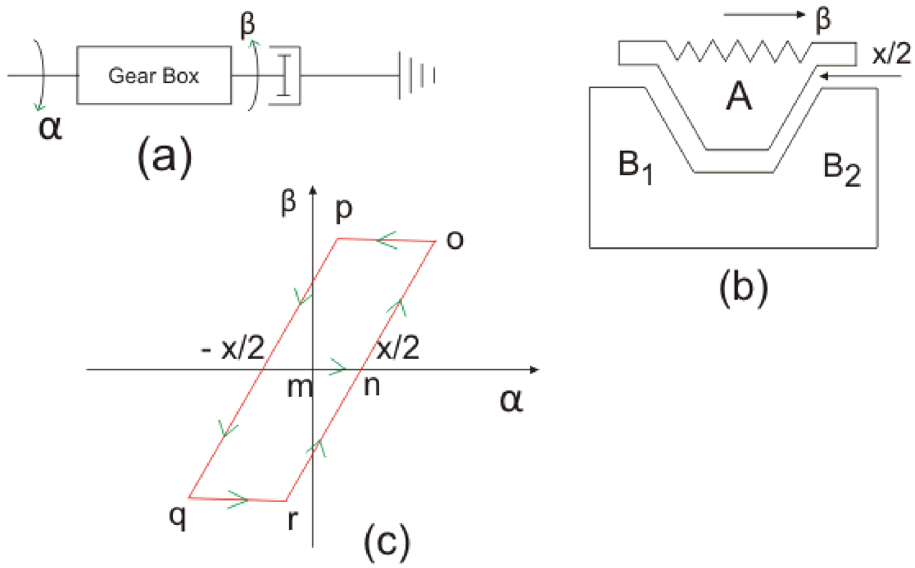


Fig (b) shows the teeth A of the driven gear located midway between the teeth B_1, B_2 of the driven gear. Fig (c) gives the relationship between input and output motions. As the teeth A is driven clockwise from this position, no output motion takes place until the tooth A makes contact with the tooth B_1 of the driven gear after traveling a distance x/2. This output motion corresponds to the segment Mn of fig (c). After the contact is made the driven gear rotates counterclockwise through the same angle as the drive gear if the gear ratio is assumed to be unity. This is illustrated by the line segment no. As the input motion is reversed, the contact between the teeth A and B_1 is lost and the driven gear immediately becomes stationary based on the assumption that the load is friction controlled with negligible inertia. The output motion, therefore, causes till tooth A has traveled a distance x in the reverse direction as shown in fig (c) by the segment op. After the tooth A establishes contact with the tooth B_2, the driven gear now mores in a clockwise direction as shown by segment pq. As the input motion is reversed the direction gear is again at standstill for the segment qr and then follows the drive gear along rn.

8. Differentiate between the SISO and MISO systems.

Ans-

1. SISO means Single Input Single Output while MIMO means Multiple Input Multiple Output.

2. In SISO system only one antenna is used at transmitter and one antenna is used at Receiver while in MIMO case multiple antennas are used.

3. SISO is used in radio, satellite, GSM and CDMA systems while MIMO is used in next generation wireless technologies such as mobile WiMAX -16e, WLAN-11n.11ac,11ad, 3GPP LTE etc.

9.. What do you mean by state transition? State the properties of state transition matrix.

Ans- The state-transition matrix is a matrix whose product with the state vector x at the time t0 gives x at a time t, where t0 denotes the initial time. This matrix is used to obtain the general solution of linear dynamical systems. It is represented by Φ.

10 Important Properties of State Transition Matrix

1. It has continuous derivatives.

2. It is continuous.

3. It cannot be singular. $\Phi^{-1}(t, \tau) = \Phi(\tau, t)$

   $\Phi^{-1}(t, \tau)\, \Phi(t, \tau) = I$. I is the identity matrix.

4. $\Phi(t, t) = I\ \forall\ t$.

5. $\Phi(t_2, t_1)\, \Phi(t_1, t_0) = \Phi(t_2, t_0)\ \forall\ t_0 \le t_1 \le t_2$

6. $\Phi(t, \tau) = U(t)\, U^{-1}(\tau)$.

   U(t) is an n×n matrix. It is the fundamental solution matrix that satisfies the following equation with initial condition $U(t_0) = I$.

7. It also satisfies the following differential equation with initial conditions $\Phi(t_0, t_0) = I$

8. $x(t) = \Phi(t, \tau)\, x(\tau)$

9. The inverse will be the same as that of the state transition matrix just by replacing ‘t’ by ‘-t’. $\Phi^{-1}(t) = \Phi(-t)$.

10. $\Phi(t1 + t2) = \Phi(t1)\,\Phi(t2)$. If $t = t1 + t2$, the resulting state transition matrix is equal to the multiplication of the two state transition matrices at $t = t1$ and $t = t2$.

10. What are the advantages of modern control theory over conventional control theory?

Ans- Advantages

It is possible to analyze time-varying or time-invariant, linear or non-linear, single or multiple input-output systems.

It is possible to confirm the state of the system parameters also and not merely input-output relations.

It is possible to optimize the systems and useful for optimal design.

It is possible to include initial conditions.

11. Define state transition matrix. And list its application.

Ans- The state-transition matrix is a matrix whose product with the state vector x at the time t0 gives x at a time t, where t0 denotes the initial time. This matrix is used to obtain the general solution of linear dynamical systems. It is represented by Φ. This state transition matrix is used to collapse all star hits that occur over an interval of time to their effective image space positions at some epoch. Inherent in the process is information that can be used to optimally adjust parameters of the motion model without a priori identification of the imaged stars.