Mechanical Engineering Department (2016-17)

Marks: 10	6ME3A: Mechatronics (Mid-Term-I)	Time: 1 Hr.
1)	Define the term "Mechatronics" and explain briefly its importance in Automation with its Applications	3
2)	List out various types of Flexible Manufacturing Systems (No description)	2
3)	Write factors which force to development of MEMS	1
4)	Define Sensors and Transducer. Also, list out various specifications of them.	2
5)	A RTD has a resistance of 100 Ω at 0^{O}C. If its resistance increases to 280 Ω when it is in contact with a hot gas, determine the temperature of the gas. α for RTD is 0.0039/^{O}C.	2

Mechanical Engineering Department (2016-17)

Marks: 10	6ME3A: Mechatronics (Mid-Term-II)	Time: 1 Hr.
1)	List out various factors which helped us in selecting and deciding a proper actuator for any mechatronics systems.	1
2)	"The positive displacement pumps are most suitable and acceptable for hydraulic systems." Give the proper justification for the statement.	2
3)	Explain briefly any three: (1) Gear Pump, (2) Vane Pump, (3) DC or AC Motor, (4) Stepper Motor, (5) Smart Material Actuator.	3
4)	Explain working of the Data Acquisition System with suitable block diagram.	2
5)	Briefly describe four different phases followed in design process to model a part.	2

Solution Mechanical Engineering Department (2016-17)

6ME3A: Mechatronics (Mid-Term-I)

Ans: 1

Definition: A philosophy in which there is a coordinated and concurrently developed, integration of mechanical engineering with electronics and intelligent computer control in the design and manufacture of products and processes.

Importance of Mechatronics:

Today's customers are demanding more variety and higher levels of flexibility in the products. Due to these demands and competition in the market, manufacturers are thriving to launch new/modified products to survive. It is reducing the product life as well as lead-time to manufacture a product. It is therefore essential to automate the manufacturing and assembly operations of a product.

Mechatronics based automated systems such as automatic inspection and quality assurance, automatic packaging, record making, and automatic dispatch help to expedite the entire manufacturing operation. These systems certainly ensure a supply better quality, well packed and reliable products in the market. Automation in the machine tools has reduced the human intervention in the machining operation and improved the process efficiency and product quality. Therefore, it is important to study the principles of mechatronics and to learn how to apply them in the automation of a manufacturing system.

Applications:

1) Design and Modelling,2) Software Integration, 3) Actuator and Sensors, 4) Intelligent Control

5) Robotics, 6) Manufacturing, 7) Motion Control, 8) Vibration and Noise Control, 9) Optics.

Ans:2

Flexible Manufacturing Systems are classified as:

- Flexible Manufacturing Cell (FMC),
- Flexible manufacturing System (FMS) and
- Flexible manufacturing Line (FML)

Further, there are three levels of manufacturing flexibility:

- *Basic Flexibilities*
  - *Machine flexibility*
  - *Material handling flexibility*
  - *Operation flexibility*
- *System flexibilities*
  - Volume flexibility
  - Expansion flexibility
  - Routing flexibility

    - Process flexibility
    - Product flexibility
- *Aggregate flexibilities*
    - Program Flexibility
    - Production Flexibility
    - Market Flexibility

Ans 3:

Following are factors which force to development of MEMS:

- Miniaturization with no loss of functionality,
- Integration to form a monolithic system,
- Improved reproducibility, reliability and accuracy,
- Low power consumption,
- Fast actuation techniques,
- Improved selectivity and sensitivity

Ans:4

Sensor and Transducer

Sensor is a device that when exposed to a physical phenomenon (temperature, displacement, force, etc.) produces a proportional output signal (electrical, mechanical, magnetic, etc.).

The term transducer is often used synonymously with sensors. However, ideally, a sensor is a device that responds to a change in the physical phenomenon. On the other hand, a transducer is a device that converts one form of energy into another form of energy.

Sensors are transducers when they sense one form of energy input and output in a different form of energy.

For example, a thermocouple responds to a temperature change (thermal energy) and outputs a proportional change in electromotive force (electrical energy). Therefore, a thermocouple can be called a sensor and or transducer.

Specification:

Range, Hysteresis, Span, Resolution, Error, Stability, Accuracy, Dead band/time, Sensitivity, Repeatability, Nonlinearity, Response time

Ans 5:

We know

$$R_t = R_0\left(1+\propto (T_t - T_0)\right)$$

where T_t is temperature and R_t is the resistance, R_0 is the reference resistance, and T_0 is a reference temperature. α is material property of RTD.

Given parameters are: $R_0 = 100\ \Omega$, $T_0 = 0^oC$, $R_t = 280\ \Omega$, $\alpha = 0.0039/^OC$, $T_t = ?$

So,

$$T_t = \frac{R_t - R_0}{R_0 \cdot \alpha} + T_0$$

$$T_t = \frac{280 - 100}{100 \cdot 0.0039} + 0 = 461.5\ ^oC$$

Solution Mechanical Engineering Department (2016-17)

6ME3A: Mechatronics (Mid-Term-II)

Ans:1

Various factors which helped us in selecting and deciding a proper actuator for any mechatronics systems are as under:

(a) the field of view and range;

b) accuracy;

(c) repeatability and resolution;

(d) responsiveness in the target-domain;

(e) power consumption;

(f) hardware reliability;

(g) size; and

(h) interpretation reliability.

Ans 2:

The positive displacement pumps are most suitable and acceptable for hydraulic systems because Positive displacement pumps are characterised by an operation that moves fluid by trapping a fixed volume, usually in a cavity, and then forces that trapped fluid into the discharge pipe. Whereas the centrifugal pump transfers the kinetic energy of the motor to the liquid by a spinning impeller; as the impeller rotates it draws in fluid causing increased velocity that moves the fluid to the discharge point.

Positive displacement pumps are usually selected for their ability to handle high viscosity fluids at high pressures and relatively low flows as their efficiency isn't affected by pressure. Whilst centrifugal pumps are the most common type of pump installed due to their simplicity, positive displacement pumps are a solution that can handle more difficult conditions where centrifugal pumps may fail.

Ans 3:

(1) Gear Pump:

Gear pump is a robust and simple positive displacement pump. They are compact, relatively inexpensive and have few moving parts. The rigid design of the gears and houses allow for very high pressures and the ability to pump highly viscous fluids. They are suitable for a wide range of fluids and offer self-priming performance.

These pumps include helical and herringbone gear sets (instead of spur gears), lobe shaped rotors similar to Roots blowers (commonly used as superchargers), and mechanical designs that allow the stacking of pumps.

Based upon the design, the gear pumps are classified as:

- External gear pumps
- Lobe pumps
- Internal gear pumps
- Gerotor pumps

Generally, gear pumps are used to pump:

- Petrochemicals: Pure or filled bitumen, pitch, diesel oil, crude oil, lube oil etc.
- Chemicals: Sodium silicate, acids, plastics, mixed chemicals, isocyanates etc.
- Paint and ink,
- Resins and adhesives
- Pulp and paper: acid, soap, lye, black liquor, kaolin, lime, latex, sludge etc.
- Food: Chocolate, cacao butter, fillers, sugar, vegetable fats and oils, molasses, animal food etc.

(2) Vane Pump

The leakage is reduced by using spring or hydraulically loaded vanes placed in the slots of driven rotor. Capacity and pressure ratings of a vane pump are generally lower than the gear pumps, but reduced leakage gives an improved volumetric efficiency of around 95%. Vane pumps are available in a number of vane configurations including sliding vane, flexible vane, swinging vane, rolling vane, and external vane etc.

External vane pumps can handle large solids. Flexible vane pumps can handle only the small solids but create good vacuum. Sliding vane pumps can run dry for short periods of time and can handle small amounts of vapor. The vane pumps are known for their dry priming, ease of maintenance, and good suction characteristics. The operating range of these pumps varies from -32 °C to 260 °C.

These pumps have various applications for the pumping of following fluids:

- Aerosol and Propellants
- Aviation Service - Fuel Transfer, Deicing
- Auto Industry - Fuels, Lubes, Refrigeration Coolants
- Bulk Transfer of LPG and NH_3
- LPG Cylinder Filling
- Alcohols
- Refrigeration - Freons, Ammonia
- Solvents
- Aqueous solutions

(3) DC or AC Motor

The most common electromechanical actuator is a motor that converts electrical energy to mechanical motion.

• Motors are the principal means of converting electrical energy into mechanical energy in industry.

• Motors: DC motors, AC motors, and stepper motors.

• DC motors operate on DC voltage and varying the voltage can easily control their speed.

• Applications: starter motors, fan motors, windshield wiper motors, etc.

• Disadvantages: More costlier, require more maintenance compared to AC motors.

(4) Stepper Motor

A Stepper Motor or a step motor is a brushless, synchronous motor which divides a full rotation into number of steps. Unlike a brushless DC motor which rotates continuously when a fixed DC voltage is applied to it, a step motor rotates in discrete step angles. The Stepper Motors therefore are manufactured with steps per revolution of 12, 24, 72, 144, 180, and 200, resulting in stepping angles of 30, 15, 5, 2.5, 2, and 1.8 degrees per step. The stepper motor can be controlled with or without feedback.

Stepper motors work on the principle of electromagnetism. There is a soft iron or magnetic rotor shaft surrounded by the electromagnetic stators. The rotor and stator have poles which may be teethed or not depending upon the type of stepper. When the stators are energized the rotor moves to align itself along with the stator (in case of a permanent magnet type stepper) or moves to have a minimum gap with the stator (in case of a variable reluctance stepper). This way the stators are energized in a sequence to rotate the stepper motor.

Types of Stepper Motor

By construction the step motors come into three broad classes:

1.Permanent Magnet Stepper

2.Variable Reluctance Stepper

3.Hybrid Step Motor

(5) Smart Material Actuator

Unlike the conventional actuators, the smart material actuators typically become part of the load bearing structures. This is achieved by embedding the actuators in a distributed manner and integrating into the load bearing structure that could be used to suppress vibration, cancel the noise, and change shape. Of the many smart material actuators, shape memory alloys, piezoelectric (PZT), magnetostrictive, Electrorheological fluids, and ion exchange polymers are most common. Shape Memory Alloys (SMA) are alloys of nickel and titanium that undergo phase transformation when subjected to a thermal field.

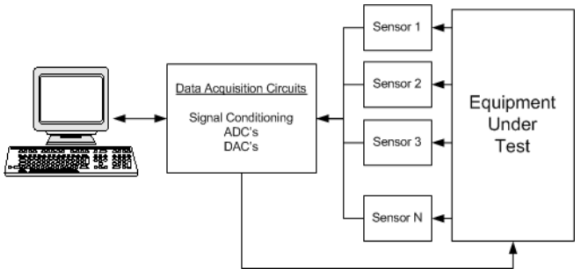
Ans 4:

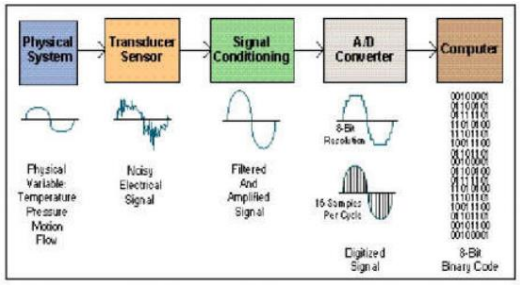
Data Acquisition System:

The purpose of a data acquisition system is to capture and analyze some sort of physical phenomenon from the real world. Light, temperature, pressure, and torque are a few of the many different types of signals that can interface to a data acquisition system. A data acquisition system may also produce electrical signals simultaneously. These signals can either intelligently control mechanical systems or provide a stimulus so that the data acquisition system can measure the response. A data acquisition system provides a way to empirically test designs, theories, and real world systems for validation or research.

Since data acquisition devices acquire an electric signal, a transducer or a sensor must convert some physical phenomenon into an electrical signal. In case of thermocouple, as the temperature increases, the voltage produced by the thermocouple increases. A software program can then convert the voltage reading back into a temperature for analysis, presentation, and data logging.

Many sensors produce currents instead of voltages. A current is often advantageous because the signal will not be corrupted by small amounts of resistance in the wires connecting the transducer to the data acquisition device. A disadvantage of current-producing transducers is that most data acquisition devices measure voltage, not current.





Ans 5:

Four different phases followed in design process to model a part:

1) Requirements analysis,
   The requirements analysis (phase 1) consists in obtaining a sufficient understanding of the problem to be solved. The difficulty of this process varies with the scale of the problem, the designers' familiarity with the problem domain, the variability of market needs, and the presence of hidden requirements that are poorly articulated in the initial problem statement. Depending on the nature of the design problem, the requirements identified in this phase may be the needs of a single customer, the common needs of a group of potential customers identified via a market survey, or societal needs identified by government regulations. concept generation,
2) Concept Generation
   Prime objective of this phase is to generate multiple design concepts that might satisfy the requirements identified in phase 1. Here we need modeling techniques that allow us to describe possible solutions with varying levels of detail dependent on the degree of detail needed to document the key elements of the concept. Since individual concepts generated in this phase may only satisfy some portions of the design requirements, it is critical that modeling at this point allow for partial descriptions of embodiments and for the easy combination of design concepts. For this reason, our models must clearly document the portions of the requirements satisfied as well as any unspecified parameters or additional requirements introduced in the concept.
3) Analysis and selection
   In this phase we evaluate potential solutions in terms of the problem requirements. This phase is eased if we have a model that allows us to compare problem requirements with design features. A particular design methodology may include various quality criteria in addition to those set by customer requirements and the regulatory environment, e.g., the design axioms of Such prefer designs with minimum information content and which satisfy each requirement by independent features of the design. One approach to evaluation is to attempt to find numerical criteria for all requirements and evaluate solutions via minimization of an overall cost function (or equivalently, the maximization of an overall value function).

4) Detailed design

The entire process is repeated to resolve open design details for the individual components of the resulting design. This is in keeping with the design heuristic "allocate resources as long as the cost of not knowing exceeds the cost of finding out." The process is inherently recursive, with each high-level design decision producing a simpler design problem at a lower level of abstraction with simpler requirements. To accommodate this, we need to be able to model the design at multiple levels of abstraction and to allow the specification of interfaces between components. These models must allow us to define static as well as dynamic (behavioural) components of the interface. Another way to make suitable decision is iteration process using chain of design decisions and changes in the marketplace demand revisions of a product.