Introduction to mechatronics system engineering essay

Mechatronics is a word originated in Japan in 1980s to denote the combination of technologies which go together to produce industrial robots. The word, mechatronics , is composed of “ mecha” from mechanism and the “ tronics” from electronics. In other words, technologies and developed products will be incorporating electronics more and more into mechanism, intimately and organically, and making it impossible to tell where one ends and the other begins. According to the Mechatronics forum, UK a formal definition of Mechatronics is “ the synergistic integration of Mechanics and Mechanical Engineering, Electronics, Computer technology, and IT to produce or enhance products and systems”. W. Bolton defines mechatronics as “ A mechatronic system is not just a marriage of electrical and mechanical systems and is more than just a control system; it is a complete integration of all of them”. A graphical representation of mechatronics, as shown in figure 1, illustrates integrated and inter-disciplinary approach of nature.

3. PNG

Figure 1 Graphical representation of mechatronics

Even though many people believe that the presence of mechanical, electrical, electronic components, and computers make a system mechatronics, others do not feel the same as there is nothing wrong with the individual identity. Hence , the term mechatronics should be used to represent a different meaning , namely ,” a design philosophy”, where mechanical, electrical, electronic components, and IT should be considered together in the design stage itself to obtain a compact, efficient, and economic product rather than designing the components separetly. A

mechatronic engineer must be able to design and select mechanical devices, sensors, and actuators, analogue and digital circuits, microprocessor-based components, and control devices such as logic gates to design modern systems.

ELEMENTS OF MECHATRONICS SYSTEM

Various elements in typical mechatronic systems are shown and are described here under.

Actuators and Sensors

Signals and conditioning

Digital logic systems

Software and Data Acquisition systems

Computers and Display devices.

Actuators and Sensors:

Sensors and actuators mostly come under mechanical systems. The actuators produce motion or cause some action. The sensors detect the state of the system parameters, inputs and outputs. The various actuators used in mechatronic system are pneumatic and hydraulic actuators, electro-mechanical actuators, electrical motors such as D. C motors, A. C motors, stepper motors, servo motors, and piezoelectric actuators. (Onwubolu, 2005) The various type of sensors used in mechatronic system are linear and rotational sensors, acceleration sensors, force, torque, and pressure sensors, flow sensors, temperature sensors, proximity sensors, light sensors.

Signals and Conditioning:

The mechatronic systems deal with two types of signal and conditioning: input and output. The input devices receive input signals from the mechatronic systems via interfacing devices and sensors, and then send to the control circuits for conditioning or processing. The various input signal conditioning devices used in mechatronic system are discrete circuits, amplifiers, analog-to-digital converters, digital-to-digital converters. The output signals are send to output/display devices through interfacing devices. (Bishop, 2002, pp. 1188-1195)

Digital logic systems:

Digital logic devices control overall system operation. The various digital logic systems are used in mechatronic system are logic circuits, microcontrollers, programmable logic controllers, sequencing and timing controls, control algorithms. (Onwubolu, 2005)

Software

And

Data acquisition systems

Digital logic systems

Signals

And

Conditioning

Actuators

And

Sensors

Computers

And

Display devices

Figure 2 Elements of a mechatronics system

Software and Data acquisition systems:

Data acquisition system acquires the output signals from sensors in the form of voltage, frequency, resistance etc and inputting into the microprocessor or computer. Software is used to control the acquisition of data through DAC board. (Bishop, 2002, pp. 1150-1188) The data acquisition system consists of multiplexer, amplifier, register and control circuitry, DAC board.

Computer and Display devices:

Computers are used to store large number of data and process further through software. Display devices are used to give visual feedback to the user. (Onwubolu, 2005) The various display devices used in mechatronic system are LED’s, CRT, LCD, digital displays etc.

STAGES IN DESIGNING MECHATRONICS SYSTEMS

The design process consists of the following stages:

Stage1: Need for design

The design process begins with a need. Needs are usually arise from dissatisfaction with an existing situation. Needs may come from inputs of operating or service personal or from a customer through sales or marketing representatives. They may be to reduce cost, increase reliability or performance or just change because of public has become bored with the product. (W. Bolton, 2003)

Stage2: Analysis of problem

Probably the most critical step in a design process is the analysis of the problem i. e., to find out the true nature of the problem. The true problem is not always what it seems to be at first glance. Its importance is often overlooked because this stage requires such a small part of the total time to create the final design. It is advantageous to define the problem as broadly as possible. (W. Bolton, 2003) If the problem is not accurately defined, it will lead to a waste of time on designs and will not fulfil the need.

Stage 3: Preparation of specification

The design must meet the required performance specifications. Therefore, specification of the requirements needs to be prepared first. This will state the problem definition of special technical terms, any constraints placed on the solution, and the criteria that will be used to evaluate the design. Problem statement includes all the functions required of the design, together with any desirable features. The following are some of the statements about the problem:

-Mass and dimensions of design.

-Type and range of motion required.

-Accuracy of the element.

-Input and output requirements of elements.

-Interfaces.

-Power requirements.

-operating environment.

-Relevant standards and code of practise, etc. (W. Bolton, 2003)

Stage 4: Generation of possible solution

This is often known as conceptualisation stage. The conceptualisation step is to determine the elements, mechanisms, materials, process of configuration that in some combination or other result in a design that satisfies the need. This is the key step for employing inventiveness and creativity. (W. Bolton, 2003)

A vital aspect of this step is synthesis. Synthesis is the process of taking elements of the concept and arranging them in the proper order, sized and dimensioned in the proper way.

Stage 5: Selection of suitable solution or Evaluation

This stage involves a thorough analysis of the design. The evaluation stage involves detailed calculation, often computer calculation of the performance of the design by using an analytical method. (W. Bolton, 2003) The various solutions obtained in stage4 are analysed and the most suitable one is selected.

Stage 6: Production of detailed design

The detail of selected design has to be worked out. It might have required the extensive simulated service testing of an experimental model or a full size prototype in order to determine the optimum details of design. (W. Bolton, 2003)

Stage 7: Production of working drawing

The finalised drawing must be properly communicated to the person who is going to manufacture. The communication may be oral presentation or a design report. Detailed engineering drawings of each component and the assembly of the machine with complete specification for the manufacturing process are written in the design report. (W. Bolton, 2003)

Stage 8: Implementation of design

The components as per the drawings are manufactured and assembled as a whole system.

OBJECTIVE:

A coffee dispensing machine has to design using Mechatronic design methodology. The machine is to be used in the university campus. The

machine should offer the coffee of user choice like latte, cappuccino, black and expresso. The machine use real coffee beans and milk for this process. The machine should identify the cup size for the particular choice and has to detect and intimate the missing and the wrong size of cup to the user.

CONCEPTUAL DESIGN:

A vital aspect of this stage is synthesis. Synthesis is the process of taking elements of the concept and arranging them in the proper order, sized and dimensioned in the proper way. Outline solutions are prepared for various possible models which are worked out in sufficient details to indicate the means of obtaining each of required functions. This is the structure of creating high-level for the system.

USER REQUIREMENTS:

The machine is to be used on a university campus. The machine will:

Offer the user choice of ingredients e. g. with or without sugar and should offer the choice of latte, cappuccino, black and expresso. The machine will use real coffee beans and milk.

Use two sizes of paper cups- large for latte and cappuccino and small for expresso. Cups will be put in position by the customer.

Missing or wrong size cup has to be detected.

The machine should accept only £2, £1, 50 pence coins and the cost of coffee will be £1. 50p. Change should be given automatically.

The cost of machine should me not more than £2000.

The time to display coin is less than 2 seconds and time to make coffee is maximum 30 seconds.

The dimension of coffee machine is 0. 5 meter* 0. 5 meter* 1 meter.

Indication for system fault, system needs service and if the coins in the box attains maximum level.

Digital display while processing is being carried in each stage to easily understand by the user so that he can communicate easily.

It should be designed in such a way that machine should give an output signals when ingredients are empty and allow to refill

Ease of maintenance

The outer model of the coffee machine is shown below

2. PNG

Figure 3- coffee vending machine

The designing of coffee machine can be classified as,

Automatic coin management system

Automatic dispensing of coffee.

AUTOMATIC COIN MANAGEMENT SYSTEM:

The automatic coin management system should recognize coin, sorting of coin, change dispensing and the control of the associated human-machine

interface. To detect the coin, the coin thickness and weight has to be considered. Since the machine will accept only £2, £1 and 50 pence the coin has to be detected properly by means of proper detection method.

After the detection the coin has to send to their respective bin for storage. If the coin £2 is inserted then change 50 pence has to be given automatically. In the display, respective value of coin or total value of coin is displayed. In the coin management system, the thickness of the coin, weight of the coin and the diameter of the coin are taken in to consideration. The table below will give detailed description of the following coin.

Coins

Thickness

Weight

diameter

Image of coin

£2

2. 50mm

12. 0gram

28. 4mm

3. PNG

£1

3. 15mm

9. 5gram

22. 5mm

1983_REV. JPG

50p

1. 78mm

8. 0gram

27. 3mm

50_PENCE_1982. JPG

Table 1- coin properties (British coin properties, 2010)

The probabilities of inserting coins in the machine are follows:

£1 + 50p

50p+50p+50p

£2 Return 50p

50p+£2 Return both the coins

Fake or counterfeit coins Return the coin

The coins are collected in their respective bins. If the bin attains 180 coins the indication has to be made and if the coins in the 50 pence bin have less than 10 coins the indication is made for the operator.

The size of £2 collecting bin should be 50 cm (200*2. 5mm= 500mm) in height; the sensor is placed in bin at 45cm (180*2. 5mm= 450mm). The size of £1 collecting bin is 63cm (200*3. 15mm= 630mm) in height; the sensor is placed in bin at 56. 7cm (180*3. 15mm= 567mm). The size of 50 pence collecting bin should be 35. 6cm (200*1. 78mm= 356mm) in height; this bin has two sensors to indicate maximum and minimum number of coins, maximum level sensor is placed at 32cm (180*1. 78mm= 320mm) and minimum level sensor is placed at 1. 78cm (10*1. 78mm= 17. 8mm).

Consider if the machine has to accept £2 coin means, first the coin is to be inserted, and then the sensor S1 senses the coin and activates the thickness and weight detector. If the detector detects £2 coin means the solenoid V1 and V2 are not energised but the solenoid V3 is energised which make the pivotable gate G3 to point towards the £2 bin. Then the solenoid valve in the 50 pence bin energised to return the change. The schematic representation of coin management is shown in figure 4.

INSERT COIN

aaaaase

50 pence bin

1 pound bin

aaaaaa S1

Thickness detector

Weight detector

G1

V1 G2

V2 G3

2 pound bin S2

V3

S3

RETURN COIN

Figure 4- schematic representation of coin management

AUTOMATIC DISPENSING OF COFFEE:

The automatic dispensing of coffee should grind coffee, fill brewing chamber, tamp down coffee grounds, brew coffee, detecting coffee cup, fill coffee cup and eject used grounds are to be made automatically. Automatic coffee dispensing process will trigger once the required money of the coffee has been received from the customers. Different procedures have to be followed to prepare different flavours of coffee.

Expresso: The coffee beans are grinded finely and 7gm of powder is used for dosage to prepare 30ml of expresso. Tamping has to be done at 134N for 2seconds. The hot water at 92ÌŠ -96ÌŠ Celsius at 9-10 Bar pressure and have to be extracted at 25 seconds. Small cup has to be used.

Latte: Expresso and hot milk at 92 degree Celsius has to be added. Large cup is used.

Cappuccino: Expresso and milk foam (2/3 of cup) has to be mixed; large cup is used for collecting the cappuccino.

Black coffee: expresso and more amount of water (2/3 of cup) is mixed and large cup is used.

The cup has to be detected by means of the sensors. The two sensors are used for cup detection. To sense the small cup, the sensor has to be placed at its height. If the expresso is selected and the sensor for the small cup activated means the valve is opened to send the coffee to the cup. To detect large cup, the sensor for the small cup and another sensor placed at the height of large cup has to be activated. If not the user has to be informed in the display “ PLACE LARGE CUP”.

EMBODIMENT DESIGN:

Power supply:

Since all electronic circuits work only with low D. C voltage it needs a power supply unit to provide the appropriate voltage supply. This unit consists of transformer, rectifier, filter and regulator. A. C voltage typically 230V rms is connected to a transformer which steps that AC voltage down to the level to

the desired AC voltage. A diode rectifier then provides a full-wave rectified voltage that is initially filtered by a small capacitor filter to produce a DC voltage. This resulting DC voltage usually has some ripples or AC voltage variations, regulator circuit can use this DC input to provide DC voltage that not only has much less ripple voltage but also remains the same DC value even the DC voltage varies somewhat, or the load connected to the output DC voltage changes. The power supply unit is a source of constant DC voltage. The required DC supply is obtained from the available AC supply after rectification, filtration and regulation.

Transformer

Rectifier

Regulator

Filter

230 V 5v

AC DC

12V 12V 12V

Figure 5- Block diagram of power supply.

SENSORS:

Proximity sensors:

These types of sensors are used to determine the presence of nearby objects. They are essentially non contact two state devices which give ON-OFF outputs. The proximity sensor often emits an electromagnetic field or

beam and look for changes in the field. The object being sensed is often referred to as the proximity sensor’s target. Different proximity sensors targets demand different sensors.

Inductive proximity sensor:

This sensor is used for the detection of ferrous metal objects over short distances. Inductive proximity sensors operate under the electrical principle of inductance. Inductance is the phenomenon where the fluctuating current, which by definition has a magnetic component, induces an electromotive force (emf) in a target object. (inductive proximity sensor, 2008)

An inductive proximity sensor has four components; the induction coil, oscillator, detection circuit and output circuit. The oscillator generates a fluctuating magnetic field the shape of a doughnut around the winding of the coil that locates in the device’s sensing face. When a metal object moves into the magnetic field of detection, eddy circuits build up in the metallic object. The sensor’s detection circuit monitors the oscillator’s strength and triggers an output signal from the output circuitry proportional to the sensed gap between probe and target. (inductive proximity sensor, 2008)

This sensor is used as a sensor S1 in the coin detecting mechanism. It’s range is about 50mm.

Strain gauge load cell:

The load cell is an electromechanical transducer that coverts load acting on it into an analogue electrical signal. Load cells provide accurate measurement of compressive and tensile loads. Load cells commonly

function by utilizing an internal strain gauge that measures deflection. Because the modulus of the elasticity of a load cell is constant the amount of strain can be calibrated to determine the force upon the train in the load cell which is measured by strain gauge transducer.

This strain gauge load cell is used because of its accuracy and its response time.

This strain gauge is used for the detection of weight. By means of calculating the force the mass of the object can be identified

Since, F= m. A

Where,

F= force,

m= mass; A= acceleration.

Mass of the coin is known, by calculating acceleration value, the force can be found. According to the force value the coin can be detected. This strain gauge works in the range of 0-50k lbs. accuracy in the range of 0. 03- 0. 05%, (load cell, 2010). It is inexpensive too. This strain gauge load cell is used because of its accuracy and its response time.

Strain gauge is attached to the object or the strained element where the force is being applied. As the object is stressed due to the applied force, the resulting strain deforms the strain gauge attached with it. This cause an increase in resistivity of the gauge which produces electrical signal

proportional to the deformation (W. Bolton, 2003, pp. 36-37) . The measurement of resistivity is the measure of strain which in turns gives the measurement of force or load applied to the object. The change of resistance is generally very small and is usually measured using a Wheatstone bridge circuit where the strain gauges are connected to the circuit.

Temperature sensor:

Temperature measurement is needed in coffee machine to maintain the temperature of water and milk. Temperature is defined as “ the average kinetic energy of the individual molecules that comprise the system”. As the temperature increases, the molecular activity also increases and thus the average kinematic energy increases. There are different sensors to measure the temperature they are:

Bimetallic strip

Resistance temperature detectors (RTD’s)

Thermistors

Thermocouples

Thermodiodes and transistors.

Among this in coffee machine the thermistor is going to use. The most commonly used temperature sensors are resistance temperature detector (RTD) and thermistor. Both are temperature-sensitive resistors.

Thermistor, a word formed by combining thermal with resistor. Thermistor is a non-linear device; their resistance will decrease with an increase in temperature, but at a much faster rate than that of RTD’s. The resistance can change by more than 1000 times. As a result, thermistor can sense minute change in temperature that is otherwise undetected by RTDs and thermocouples, (W. Bolton, 2003, pp. 43-47).

Thermistors are small, inexpensive devices that are most commonly made of metal oxides such as those of chromium, nickel, manganese and cobalt. The metals are oxidised through a chemical reaction, ground to a fine powder, then compressed and subject to very high heat. These oxides are semiconductors. Thermistors can be classified into two types depending on the temperature coefficient of resistance (k). If k is positive, the resistance increases with increasing temperature, and the device is called a positive temperature coefficient (PTC) thermistor or posistor. If k is negative, the resistance decreases with increasing temperature, and the device is called a negative temperature coefficient (NTC) thermistor. NTC thermistors are mostly used in temperature sensing devices where as the PTC thermistor are mostly used in electrical current control devices.

The NTC thermistor is going to use in this coffee machine to sense the heat of water and milk. Thermistors respond quickly to temperature changes, and they have a higher resistance, so junction effects are not an issue. Typical accuracies are 1%, but the devices are not linear, have a limited temperature or resistance range and can be self heating. Compared to other sensors, thermistor have a limited measuring range, typically from -80 to

150 degree Celsius. To measure the temperature of water and milk this range is more enough.

Advantage of using thermistor:

High and fast output.

Manufactured in almost any shape and size.

Very high degree of accuracy.

Good stability and repeatability.

Has the ability to withstand mechanical and electrical stress.

Temperature controller:

The PID controller is used to control the temperature in the coffee machine. The purpose of using PID controller is it eliminates offset of the proportional mode and provides fast response. The three adjustment parameters here are proportional gain, integral time and derivative time. PID controller is the most complex of the conventional control mode combination. The PID controller can result in better control than the other controllers. The PID controllers are mainly used to control the process parameters like temperature, flow, etc.

Level sensor:

The measurement of level of the water and milk in the tank of coffee machine is very essential. There are number of devices to measure the level of the liquids in the tank. There are two methods in measuring the liquid they

are direct and indirect method. Here direct method is going to use because the level if the liquid in the tank can be measured by means of float method, (W. Bolton, 2003, pp. 41-42).

The most commonly used design in float type is hollow metal ball or sphere. Here there is no restriction to the size, shape or material used. The design consists of a ball float attached to a rod, which in turn is connected to the lever arm. A slider is attached in the lever is connected to the potentiometer. By means of this arrangement the level can be measured. The water for the machine is continuous that has to be controlled. The level in the water tank can be controlled automatically.

The control system maintains water level in the storage tank. The system performs this task by continuously sensing the level in the tank and adjusting a supply valve to add more or less water to the tank. The desired level has to be set by the operator.

The level transducer measures the level within the tank by using the float and potentiometer arrangement. The level transducer sends the signal which is the feedback for the control device. This feedback is compared with the desired level value to produce the required control action that will position the level control as needed to maintain the desired level. The level controller used here is PID controller. The block diagram of automatic tank-level control system is shown below.

Infra red beam sensor:

Infrared beam sensors used for detecting the cups. Consists of a transmitter and a receiver, and the integrated amplifier can produce infrared beam. The

LEDs should be properly covered with a reflective material like glass or aluminium foils on the sides to avoid the spreading of the IR beam and to get a sharp focus of the beam. The receiver uses a sharp IR module. When the IR beam from the transmitter falls on the IR module, the output is activated this activates the relay and deactivated when the beam is obstructed. It has highly reliable performance. The operating range of this sensor is 0-6m. Operating temperature of this sensor is -20 degrees centigrade to 60 degrees centigrade. Aperture angle of infrared beam sensors is +/- 8 degrees. (sensors, 2010)

Solenoids:

A solenoid is a device which is used to convert an electrical signal in to mechanical motion usually in straight line. The solenoids are used in the coffee machine for various purposes like coin management, sending the coffee bean in to the grinder, to open the 50 pence bin to give change when £2 coin is inserted.

The two major parts in the solenoids is coil and movable iron core. The coil used here is to be DC which when energised pulls the core inside it and this result in the mechanical motion of the core. The amount of force by which the core is pulled depends on the amount of current flowing in the circuit and the number of coils. The solenoids are very cheap and its works under 24V DC.

D. C Motor:

The DC motors are widely used in modern control system and as a final control element in positional or speed control system. The D. C motor is used

for the purpose of grinding the coffee beans. This motor has to be controlled. This can be done by means of closed loop control. This speed controller is done by means of pulse width modulation controllers. This has the advantage that its drives the bipolar power transistors rapidly between cut off and saturation where operation is very efficient. (B. Histand & Alciatore, 1999) Feed back is used in this circuit to modify the motor speed even if the conditions are changed.

Hydraulic pumps:

The hydraulic pump is used for the purpose of pumping the water and milk from the tank. The reason for using hydraulic pump is it converts the mechanical energy supplied into hydraulic energy by lifting water or milk to higher levels. Hydraulic energy refers to potential and kinetic energy of a liquid. Hydraulic pumps are the energy-absorbing machines. Since, it requires mechanical power to drive. Lifting of water or milk to higher level is carried out by the various actions of pumps such as centrifugal action, reciprocating action etc. (hydraulic pump, 2010)

Power, P = = =

Flow rate, Q=

Power, P= pressure * flow rate

The advantage of using hydraulic systems are it is easy to produce and transmit hydraulic power, it is uniform and smooth, balancing hydraulic forces is easier, it is easy to maintain , weight to power ratio is very less, it is

easy to maintain, maximum fluid flow, frictional resistance is less and hydraulic systems are safe and compact.

Gears:

The gear is used during the tamping process. The process is based on the relative position of the shaft axes and the position of the teeth on the wheel. For this purpose, helical gear is used in this process. Helical gears are simple modification of spur gears. A helical gear has teeth in the form of helix around the gear. The angled teeth engage smoothly than do spur gear teeth. This causes helical gears to run more smoothly and quietly than the spur gears. This type of gear is used in high-speed application. Because of high-speed, pressure is produced.

Where, pressure = mass * acceleration.

The selection of ball and roller bearings for gear is considered upon the following factors, they are

The load carrying capacity and the nature of the load

The speed of shaft in R. P. M

The anticipated life of bearings.

Magnitude and direction of loads.

The proportion of thrust to radial load.

Human machine interface:-

Human machine interface is an important part to design. As this is an automatic machine and the inputs to the machine are from the user, so there should be an interface between these two. This is accomplished with the help of buttons placed on the front panel. Also the touch sensors located at the back of each button are responsible to transfer the user inputs to the machine. The LED display informs the user regarding the process and intimate any faults in the system.

Push buttons:

The push button is used for the purpose of selecting the variety of coffee by the user. There are four push buttons in the machine.

LED display:

The dispensing machine should be capable of outputting text signals so that the user will know the process present state through LED display. Since the machine is made to be user friendly all the process happening in the machine as to informed to the user. If the coin is inserted that has to be informed to the user. The microprocessor is used to store all the information that has to be displayed for the ongoing process. If suppose, milk in the empty means through the level sensor the signal is sent to the microprocessor according to that it will send the output to the display as ” MILK TANK EMPTY”.

MICRO-CONTROLLER:

It is the brain of coffee machine. The microcontroller contains a microprocessor, memory, I/O capabilities, and other on-chip resources. It is basically a microcomputer on the single chip. The main purposes of using the micro-controller are low cost, versatility, ease of programming and small size. This micro controller is physically embedded in the system to perform the control functions, (Onwubolu, 2005, pp. 205-256) .

The PIC micro controller is the most commonly used micro-controller. This has various features like analogue to digital (A/D) and digital to analogue (D/A) converters, timers, digital I/O ports and a serial communication interface. The temperature and flow sensor gives analogue value that will be converted to digital in the micro-controller. So there is no need for external analogue to digital (A/D) converter in this process.

Communication:

Communication betwee