Embedded System Design for "e- Stacapult*"

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Abstract - Industrial control systems consist of number of variable parameters like temperature, pressure, flow etc. The parameters themselves are variable and so the output of the system also varies within certain limits decided by tolerance of the parameters. While learning multivariable control system, it is difficult to imagine these concepts i.e. the effect of variation in governing parameters on the output of the system. A tool has been developed called "e-Stacapult", demonstrating the importance of controlling parameters on output. The tool is based on Statapult equipment based on the principle of Catapult developed by Archimedes in early BC. It consists of a small ball thrown by a lever supported by an elastic band. This distance of the throw depends on the tensioning force (stretching) of the band, which depends on the stretched length of the band, which depends on the support positions. The time for which the stretching force is applied is also important. The observations are taken by changing the input parameters like stretched length, support positions and time of stretching. The output i.e. the distance of throw is measured which also depends on the weight of the ball.The data is processed by a suitable program correlating various parameters with output, so that a set of parameter to give particular output can be manipulated and verified.

Keywords- Statapult, e-Stacapult, Multivariable Control System, Data Collection, Data analysis,Quality management

1 INTRODUCTION

AN attempt has been made in this project to prepare a tool which can give hands on experience of this kind of system. Tool consists of hardware simulator named as "e-Stacapult" along with electronic control and software analysis backup. When a student learns multivariable Control System, variable input parameters are generally designated as $\alpha 1$, $\alpha 2$… αm etc. $\beta 1$, $\beta 2$… βm etc, $\gamma 1$, $\gamma 2$...and so on. Output parameters may be designated as o1,o2…etc.

For a student who is not exposed to actual operation of Control Systems, it is difficult to imagine what these variables signify. In a practical case, these may correspond to parameters like Temperature, Pressure, and Flow etc. and output may be in the form of displacement of

mechanical component. To make better understanding, instead of having only software simulation, it was decided to develop hardware simulator capable of generating variable output which can be measured and based on 3 to 4 variable input parameters. Data is collected by carrying out various runs of hardware simulator. This data is processed using suitable software and result of analysis can be used for validation of data collected. The paper basically focuses on distinct sections like, Hardware simulator with electronic control, Analysis software, Data transfer to the remote location, Data analysis.

Hardware simulator design is based on the famous device Catapult, invented by Archimedes. This device was used to throw large stones on enemy ships when ships reach a particular distance from shore on which the Catapult was located. He found that the distance of the throw depends on various parameters like weight of the stone, angle of inclination of throwing lever etc. The stone follows the path of trajectory decided by these parameters and ultimately strikes on ship.

Hardware under consideration is having similar constructions with some modifications to make the parameters measurable and have automatic operation, so that repeat accuracy can be achieved.

The measured parameters data is analyzed using Excel or MATLAB to establish specific relationship for specific output which will have specific input set.

The entire report is divided into various sections. Section 2 explains about operational working of the Hardware tool of the system. Details of need of Electrical and Electronic Systems are discussed in Section 3. The operation of the system is explained in Section 4. Process of data collection and Data analysis is discussed in Sections 5 and 6 respectively.

2. HARDWARE UNIT

Diagram shows a schematic of Hardware details. e-Stacapult unit consists of vertical support arm carrying four

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***NOTE : THE NAME OF THE INSTRUMENT" e-Stacapult" IS BEING DEVELOPED BY THE AUTHOR HIMSELF.**

positions for support pins, a moving lever carrying a cup for keeping a ball is hinged between two support blocks. The angle of the lever can be adjusted. This lever carries five positions on which the tension belt can be supported. An elastic band is located between a hook and tension position which is always in stretched position due to increase in its length.

When the lever is released carrying a ball, it hits stopper pin which may be located at four different positions. So distance of the throw depends on inclination angle α of the lever and position of the stopper pin. It should be remembered that angle α must be higher than stopper pin position angle.

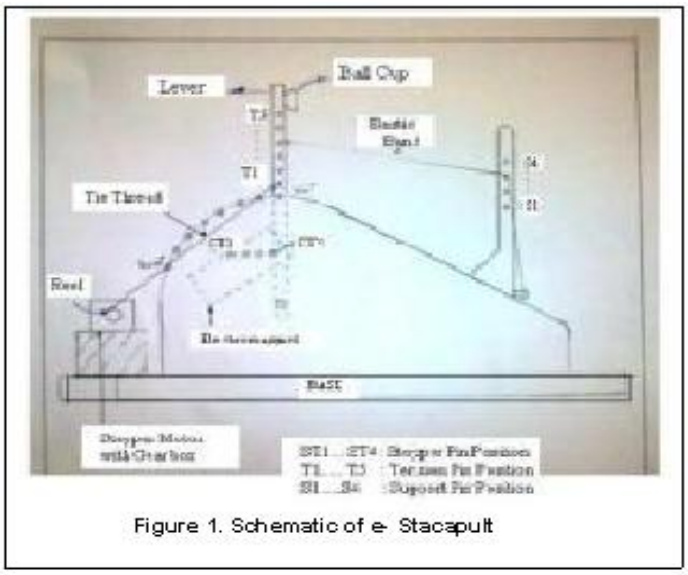

Figure 1. Schematic of e- Stacapult

Angle of inclination can be adjusted according to angle scale provided on the support i.e. from 90 degrees to 160 degrees, with accuracy of 5 degrees.

Side supports are fixed on sturdy wooden base. The vertical arm, lever, Support plates are prepared from good quality wood.

It should be noted that there are five tension positions t1,t2,…,t5. Four support positions s1,s2,…,s4, four stopper pin positions st1,st2,…,st4 and about 14 angle positions of the lever. All these are variables and the distance of the throw depends on these four set parameters.

Unit is securely fixed on table and the distance of the throw to be measured using standard meter tape.

3. ELECTRICAL AND ELECTRONIC SYSTEM

It has been thought that there may be human errors if lever is operated manually for taking consistent reading for same angle setting. Secondly an additional parameter i.e. stretching time can be introduced to observe whether the time of stretching has any effect on distance of the throw. To achieve this, system is provided with automation to some extent.

So, there are chances of introduction of human errors due to manual operation and desired setting of angle may deviate. When the operator Pulls the lever and holds it for longer time, he may experience stress.

If the effect of Time on distance thrown is to be observed, then operator will have to rely on devices like stopwatch and errors may occur in measuring time.

These errors can be reduced by controlling and monitoring the parameters using various Electrical and Electronic Control Systems.

3.1 Parameters to be monitored and controlled

Human errors can be reduced by implementing automation technique for various system parameters. The main parameters are angular position of lever, releasing of lever and monitoring stretching time. The angular position can be controlled by clamping the lever at required position against tension of the elastic element by certain force.

To achieve this, side supports are provided with a pair of Electromagnet, facing towards moving lever. The lever is provided with a pair of soft steel attraction plates located such that they will face Electromagnet with small gap of around 0.5 mm between plate. Electromagnets are designed for operation on 12 V DC for safety purpose. A Stepper motor along with a gear box is used carrying a reel with tie thread to pull the lever, is used. By setting the number of pulses for stepper motor the pulling of the lever against tension of elastic element is achieved. The use of stepper motor gives open loop control.

And control of the stepper motor movement and energization and deenergization of Electromagnet is done by using ARM Processor.

The main benefit of using ARM Processor is flexibility and ease of operation of the system.

Power supply is used to convert Mains supply of 230 V to 12 V DC for operation of electromagnet and timer circuit and Processor Circuit.

4. OPERATION OF THE SYSTEM

The operation of the system is divided into following parts.

4.1 .Stepper Motor and it's control

The lever carrying the ball cup is to be pulled against elastic band tension so as to achieve required angle of inclination. That angle can be adjusted between 100 degrees to 160 degrees in the steps of 5 degrees. For pulling the lever a strong thread is used, one end of which is clamped to the lever and thread is wound over a reel mounted on shaft of the a gearbox connected to a shaft of stepper motor. Other end of tie thread is securely clamped to reel so that when motor is rotated, say in clockwise direction, the rope pulls the lever and after reaching the preset position, lever gets clamped due to Electromagnet's force and after clamping, motor rotates in opposite i.e. in anticlockwise direction, loosening thread, so that free movement of the lever is possible. Purpose of using reduction gearbox is to increase torque to achieve accurate forward and reverse rotation of the shaft. A stepper motor is selected which can give particular angular rotation for each pulse supplied to it.

Stepper motor is especially suited for such type of applications because essentially it is a device which converts input information into digital form i.e. pulses to an output which is mechanical i.e. movement in degrees.

4.2 ARM Processor

ARM stands for Advanced RISC Machines. ARM microprocessor was developed to serve as CPU of a personal computer. Its version at that time was ARM6. It is a 32 bit processor with 32 bit ALU and a file of 32 bit general purpose registers. It can address 4 GB of memory. It has variety of addressing modes. It has three stage pipeline to execute instructions. Three stages are, Fetch, Decode, Execute

Most of the instructions in ARM require only one cycle for execution. Some instructions may require more than one cycle for execution like multiplication. ARM family of processors are mainly for low cost, low power applications like portable computer, cellular phones, automotive engines, embedded applications etc. The recent versions of ARM processor i.e. ARM 7 and ARM 9 have fast computation speed and low power consumptions. ARM does not manufacture chips but gives design. It issues license to other chip manufacturing companies, which give their own name to their product built around ARM processor.

4.3 Power Supply System

Power supply is used to provide the power for control circuit operation. As stated earlier, the electromagnets are designed for operation on 12 V DC supply and approximate value of current required for each magnet is approximately 0.5 A to 0.6 A each. To get better regulation, power supply used is rated for 2A.

Power supply selected for electromagnet is of unregulated type since small voltage drop in the supply of electromagnet will not affect its operation to substantial extent.

Power supply used for digital timer circuit is 12 V regulated as per since the input voltage variations to digital timer supply may affect its operation. So voltage regulator IC 7612 is used and required differential for power operation of IC is minimum 3 V. The unregulated or raw DC should be minimum 15 V on load.

Considering the voltage drop in transformer secondary and also voltage drops across bridge rectifier diodes, secondary voltage of transformer feeding digital timer power supply is taken as 18 V. This will also take care of primary voltage variations to extent of +/- 10 V.

To reduce ripples, bridge rectifiers are used to convert transformer secondary AC voltage to required DC voltage. To reduce the effect of current in Electromagnet on power supply to digital timer circuit, different secondary are used to give power supply to Electromagnet and also to digital electromagnet timer.

A DPST (Double Pole Single Throw) switch is used to switch ON mains supply alomg with 230 V indicating lamp indicating presence of supply. A 0.25 A fuse is used for protection circuit.

4.4 Operation of the System

The flow wise operation is described as follows. Figure 2 can be referred, which is drawn below.

1. Ensure the home position of the lever.
2. Set positions of support pin, tension pin and stopper pin as per requirement.
3. Set required angle of inclination of lever.

4. ARM Processor will define number of steps to be given to stepper motor for particular angle movement.
5. Stepper motor will start rotating so as to pull tie rope to achieve required set angle position.
6. Electromagnets will get switched ON and hold the lever.
7. Stepper motor will rotate in opposite direction so as to loosen the tie rope.
8. Timer counting will start.
9. After elapsing set time, supply of Electromagnet will get removed. Lever will get thrown due to elastic band force and will strike on stopper pin releasing ball through ball cup.

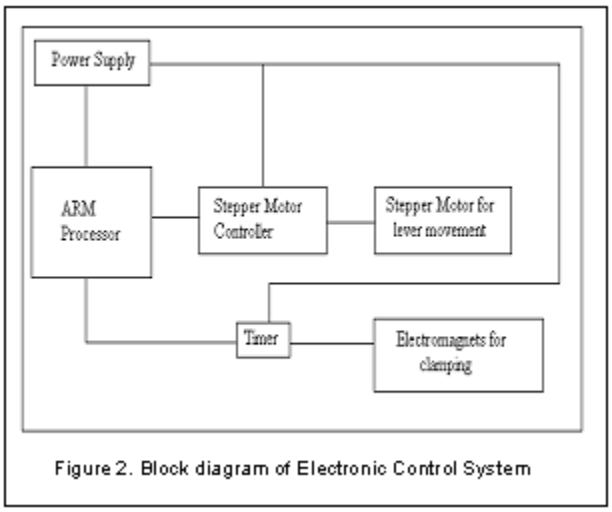

Figure 2. Block diagram of Electronic Control System

5. DATA COLLECTION

As stated earlier, e-Stacapult is to be used to understand the aspect of multivariable systems. These multivariable systems are widely referred in statistics, project management, quality management, Control system etc... Output of multivariable system is function of various input parameters which may be or may not be correlated with each other. Output of the system may be correlated with certain mathematical equation that may be established by measuring set of values that can give certain output numerically for variation in input parameters.

Input parameters may have variation continuously between its upper and lower limit in practical case.eg, If temperature of the furnace is considered as one of the parameters, variation in temperature does not occur in steps but occurs continuously. However it is difficult to simulate such system using mechanical simulator like e-Stacapult.

So the data collection is to be done considering parameters occurring at various positions.
E.g. the support is having 5 positions, so preferred readings reasonably giving good variations is at position s1, s3, s5.

In e-Stacapult simulator, mechanical variations can be created by changing :

Support position s1, s2, s3, s4, s5
Tension position t1, t2, t3, t4
Stopper position st1, st2, st3, st4
Angle position from 100 degrees to 160 degrees in steps of 5 degrees

In addition, it is possible to add two more variables.
(A) Weight of the ball : By using heavy and light ball, variation in the distance of the throw can be noted.
(B) By changing the amount for which tension is applied that can be done by changing time for which timer is ON.

It will be observed that there can be number of variables for same output. It has been decided to make 10 % sample observations with same time setting and 5 % more sets by varying the time. Same ball is used for taking such observation. Following chart can be referred as the sample chart.

Case No.	Support Pin Position	Tension Pin Position	Stopper Pin Position	Angle Position (degrees)	Distance of The Throw(cm)
1	S1	T1	St1	100 120 160	D1
2	S3	T1	St1	100 120 160	D2

Table 1. Sample Observation Chart

In the similar way, more sets of observations can be noted by taking different combinations of the parameters.

6 . DATA ANALYSIS

Data collected is analyzed using suitable software like MATLAB. It will be observed that, output becomes response having abstract surface. By using interpolation technique, it is possible to predict performance or output of required value.

From the collected data, behavior of the system can be analyzed by drawing histogram, Response Surface etc.

7 . CONCLUSION

The concept of multivariable input Control Systems can be well understood by using a mechanical simulator, e- Stacapult along with the suitable data processing tool or software. Improvements are possible in this system as per need.

8 . REFERENCES

[1] www.ncmrcompany.com

[2] www.sixsigmaproductsgroup.com

[3] MATH AND MEASUREMENT- THE STATAPULT, LAB JOURNAL

[4] Statapult Exercise, Six Sigma Green Belt Certification Course

[5] Catalogue of Statapult

[6] "Electric Machines And Power Systems" by Vincent Del Toro, PHI Publications.