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Control System for Retaining the Orientation of Cables in a Suspension Bridge

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Abstract- Orientation of cables in a suspension bridge is a major factor affecting the stability of the bridge. In this paper we are proposing a new method of controlling the orientation of cables of a suspension bridge with the help of gyro and actuators by using an appropriate control system with negative feedback.

Index Terms- Suspension Bridge, Cable Suspenders,Control System, Automation, Gyro

I. Introduction

The basic design of a suspension bridge has been in use for centuries: thousands of years ago, people crossed waterways and chasms by swinging hand over hand on suspended cables. Later, walkways were hung from the cables to make the process easier, and the original vines and ropes began to be replaced with chains. A suspension bridge is a type of bridge which is built by suspending the roadway from cables attached to a master cable which runs above the length of the bridge. The design of a suspension bridge is simple and straightforward, and takes advantage of several techniques to distribute the weight of the bridge safely and evenly. Suspension Bridges have received more attention due to their ability to cover the large spans. For bridging the long and unsupported spans, the Suspension Bridges present the most elegant and efficient structural solution.

Effect of aerodynamic forces on suspension bridge is predominant at Bridge Deck and Cables. When aerodynamic forces acts, the bridge deck will have a tendency to fail and at the same time the cables will have a tendency to change its orientation from initial position. In this paper we are focusing on the orientation of cables and are proposing a method to overcome the same.

A gyroscope shall be used for this purpose. Gyroscope is a device for measuring or maintaining orientation, based on the principles of angular momentum. Mechanically, a gyroscope is a spinning wheel or disc in which the axle is free to assume any orientation. Although this orientation does not remain fixed, it changes in response to an external torque much less and in a different direction than it would with the large angular momentum associated with the disc's high rate of spin and moment of inertia. The device's orientation remains nearly fixed, regardless of the mounting platform's motion, because mounting the device in a gimbal minimizes external torque.

Gyroscopes based on other operating principles also exist, such as the electronic, microchip-packaged MEMS gyroscope devices found in consumer electronic devices, solid-state ring lasers, fibre optic gyroscopes, and the extremely sensitive quantum gyroscope.

II. Proposed System

Orientation of cable is major factor that must be maintained for aerodynamic stability of suspension bridges. The proposed system consists of a gyro, Analog to Digital Convertor, processor, driver circuit and an actuator as shown in the figure. The gyro reads the position of cables in x, y and z axes and feeds data to the processor through A/D. The processor compares the value from gyro to the threshold value, that is, the desired value of cable orientation.

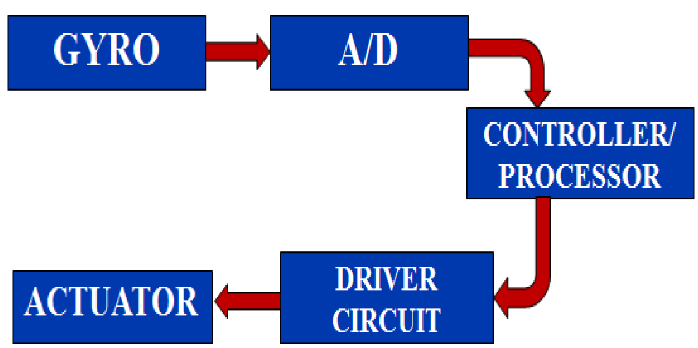

Fig 1 – Block Schematic of Proposed System

If there is a variation in the actual values from desired value, then the processor gives appropriate signal to the actuation circuit consisting of the driver circuit and the actuator.

The gyro is mounted on the cables and actuator is appropriately connected to the end of cables.

III. Control System

In order to make the above mentioned system more effective, we need to design an appropriate control system for the same.

The control loop uses negative feedback for controlling the position of cables. The threshold value of cable position is the primary input for the control loop followed by summing point and then by a controller and actuator driven by appropriate driver

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circuit. The position of the cable is fed back to the summer using the gyro. The feedback is negative so that it forms a simple feedback type to control the position of the cables.
The figure below shows the control system and signal flow graph of the proposed system.

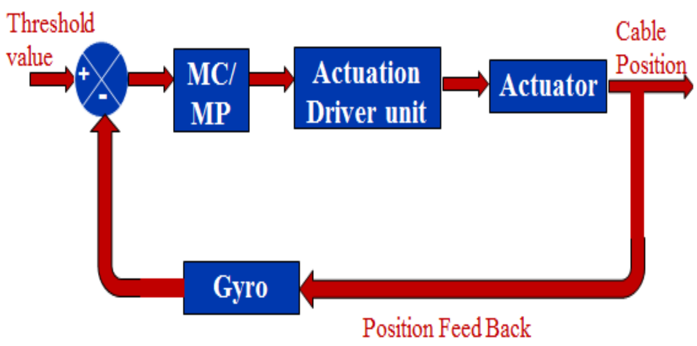

Fig 2 – Closed Loop Control System

The threshold value or desired orientation of cables are fed to the processor which initiates the actuation using actuator circuit and the position of cables are observed by the gyros mounted on them. The position values of the orientation of cables are sent back as a negative feedback to the summer where it is summed with the threshold value.

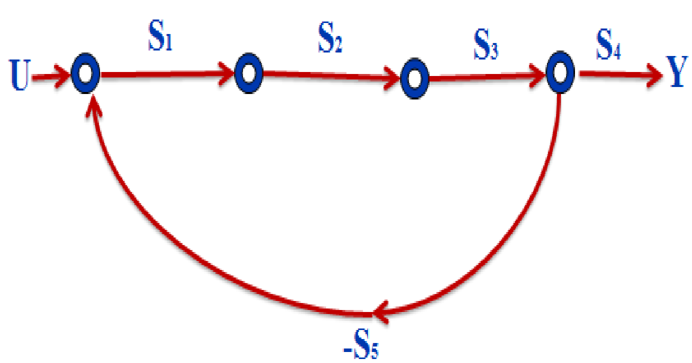

Fig 3 Signal Flow Graph

Sl. No.	**Threshold Value**	**Feedback Value**	**Actuation Value (= Threshold – Feedback value)**
1	1,2,1	1,2,1	0,0,0
2	1,2,1	2,2,5	-1,0,-4
3	1,2,1	-3,-4,-2	4,6,3

Table 1 – Sample Values

It is very clear from the table that, when there is a positive change in the cable position, the controller initiates a negative actuation and if there is a negative change in the orientation, the controller initiates a positive actuation. This is because of the use of negative feedback.

IV. IMPLEMENTATION

Fig 4 – Prototype for testing

The above shown figure shows the prototype developed for testing the proposed system. The gyro is attached to the cables and the actuation is given at the end using electric motor with appropriate coupling. Initially, the system will be stable and the gyro shows the threshold readings.

Now an external disturbance is introduced using an air blower which causes the cables to deviate from its mean position which is observed by the gyro and fed back to the controller. Now the controller gives signal to the driver circuit by sending a logic high value to the isolator and initiates the actuation.

The controller stops actuation when the cables attain back their mean position.

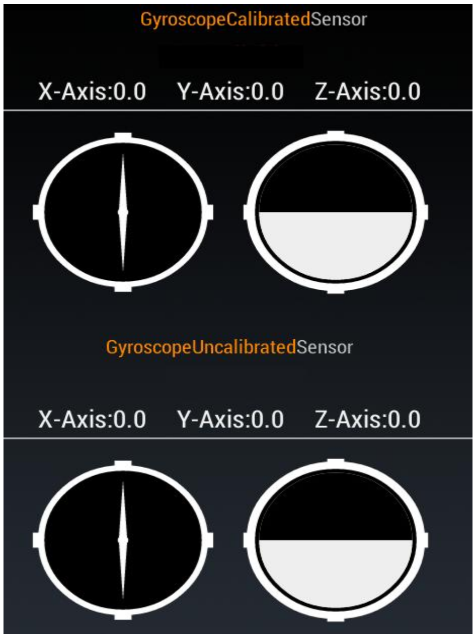

Fig 5 – Zero reading of gyro

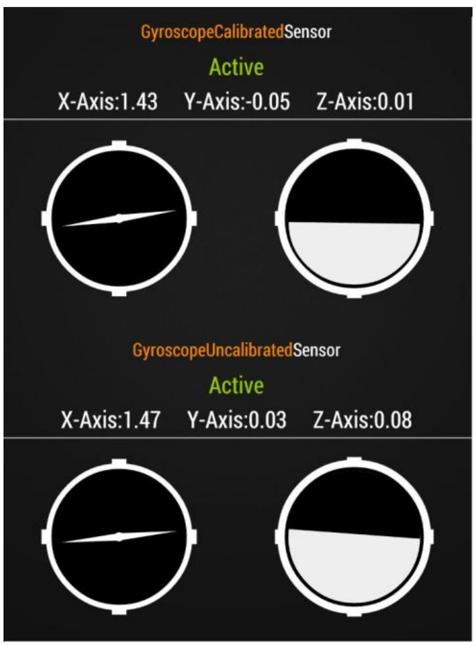

Fig 6 –Gyro Reading at Mean Position

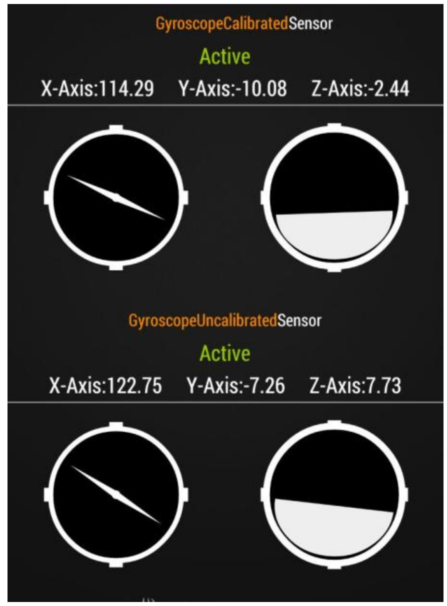

Fig 7 – Gyro reading after introducing external disturbance

V. FUTURE WORKS

The proposed system may be implemented in real time with the help of more accurate gyros and hydraulic actuation systems. Also the system may be made more efficient by designing a feed forward system instead of a feedback system.

VI. CONCLUSION

The change in orientation of cables in a suspension bridge is a major problem and this was addressed successfully at the design level by introducing a closed loop control system. This system may be modified so as to increase the efficiency by replacing the feedback with a feed forward control system.

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