

Design and Implementation of a Warning System for Detection and Prediction of Earthquakes

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Abstract—The main aim of this project is to build a cost effective and time critical electronic device that can predict and forewarn an earthquake by acquiring and processing the underground P waves and subsequently rejecting other similar acoustic signals and vibrations occurring along with it, thereby nullifying the probability of false alarms. The idea is to detect the P waves, which constitute a part of the seismic acoustic waves that are released and move up towards the crust on an event of tectonic movements deep under the earth's surface eventually giving rise to an earthquake as they surface with the first trace of its occurrence and alarm the surrounding areas. The principle used for designing the device is the effect of magnetostriction on P wave velocity when it is passed through a ferromagnetic rod. Also, the probability of a false alarm may be zeroed down by using a High temperature medium. The device is expected to provide real time data acquisition, analysis and processing, and correspondingly provide an alarm in case an earthquake is about to occur.

Index Terms—Earthquake prediction, P wave detection, electronic control module, digital signal processor.

I. INTRODUCTION

Despite all the advances made, the idea of accurate prediction and monitoring of earthquakes still remains a vision of unachieved. We need to increase further the time margin between a potential warning and its eventuality and also simultaneously get rid of any possibility of erroneous detections leading to false alarms, and the use of a system consisting of a magnetostrictive sensor combined with a high temperature medium will enable us in generating a significant leap-through in the field of Earthquake prediction technology development.

The electronic device is aimed at sensing and detecting the acoustic longitudinal waves that are generated during a tectonic movement and reach the surface before the vibrational disturbance. Also, use of acoustic sensing instead of the traditional vibration sensing reduces the cost and size significantly without compromising on its accuracy and viability.

The overall system deals with the characteristic change in velocity of P-waves for effective detection of a forthcoming quake. The effect of magnetostriction on any longitudinal elastic wave may be used for a full-proof system performance. Simultaneously, the characteristics of P waves with changes

in temperature may be incorporated to build a stable, reliable and affordable false alarm prevention system.

II. OVERVIEW

A. Seismic Acoustic Waves

An earthquake, which is a result of a sudden release of energy in the Earth's crust, involves an outburst of a combination of different types of acoustic signals due to underground tectonic movements viz., P waves, S Waves, Love waves and Rayleigh waves. The P waves are supposedly the fastest of all the waves and are unique due to its longitudinal orientation, thus being non-destructive, and hence, with a reliable detection mechanism, can aid in accurately predicting and warning a forthcoming quake.

B. Proposed Model

The development of this system is strongly concept driven. The proposed model is intended to establish the role of P wave detection- an incontrovertible marker in the prediction mechanism of a forthcoming destructive earthquake. Two important constraints formed the basis for designing the architecture of the device model:

- 1) Accurate detection of the wave (Magnetostrictive Effect).
- 2) Reliable verification of the detected wave.

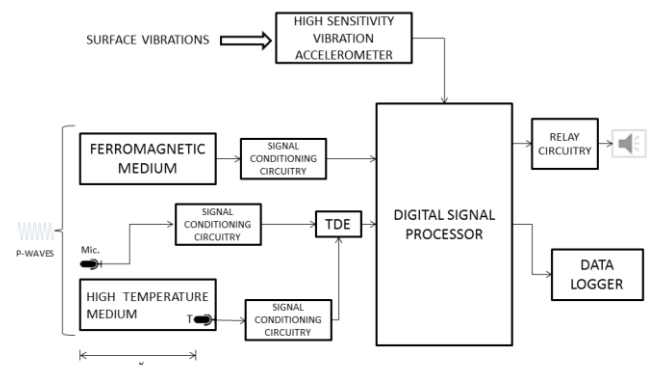


Fig. 1. Block diagram of the system.

III. CONCEPTUAL DESIGN OF WARNING AND ALERT SYSTEM

The various velocity alterations which a P wave is expected to go through as it passes through two different media: ferromagnetic rod and high temperature medium marks the essence of the warning and alert system. The velocity V of a longitudinal wave in a magnetostrictive cylindrical rod is given by [2]:

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$$V = \sqrt{\frac{E^B (1 - K^2)}{\rho}}$$

where E^B , K^2 and ρ are the Young's modulus for constant flux, the magnetomechanical coupling factor, and the mass density of the rod. The velocity V will vary with ΔE effect and K^2 [4]. The relative velocity change $\frac{\Delta V}{V_0}$ is given by

$$\frac{\Delta V}{V_0} = \frac{V - V_0}{V_0} \approx \frac{1}{2} \left[\frac{E^B (1 - K^2)}{E_0^B (1 - K_0^2)} - 1 \right]$$

where the subscript 0 denotes E^B , K^2 and V at H_e (ΔE effect) = 0.

The High temperature medium may consist of alloy of low melting temperature such as a combination of Pb (37.7%), Bi (42.5%), Sn(11.5%)[5]with a melting point of 72 °C. The velocity variation of P wave is close to about 2.4% between 2~3 °C about the melting temperature (See Fig. 2) as compared to the velocity at 12 °C.

As per the design, a ferromagnetic material with a positive magnetostrictive constant (λ) under a correctly chosen tensile stress(such as Metallic Ribbon Glass) [2] is proposed for the main sensing mechanism for the P wave.

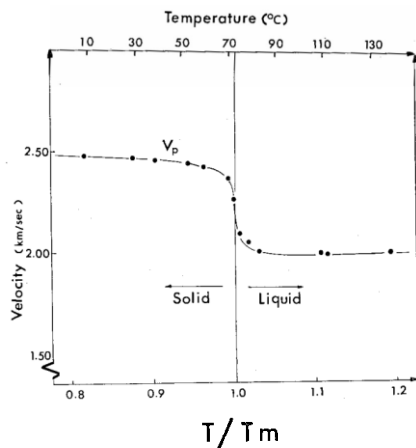


Fig. 2. P wave velocity variation with temperature.

Application of magnetostrictive effect with respect to interference of a longitudinal wave (P wave) forms the tool for the detection process. When a longitudinal wave passes through a ferromagnetic system (consisting of a ferromagnetic rod suspended between a well calibrated system of electromagnets providing a constant magnetic field), each and every particle of the wave suffers a shift in its velocity profile due to the domain shifting process in the ferromagnetic material [1]. As a result, there occurs a suitable increment in the wave velocity after the longitudinal wave crosses the system. The variation in temperature in medium causes a drastic change in elastic property of the wave. The particles of the P wave spectrum undergo systematic shift in their velocity profile due to which the velocity of the wave sharply decreases with the increase in temperature. The process of decrement of wave velocity as the wave passes through a high temperature medium provides a unique mark

of identification of a typical P wave [5].

A. Mechanism of Operation

The alterations in the wave velocity as it passes through the media are tapped (v_1) by measuring the change in magnitude of the bias field for wave detection and a microphone-transducer setup aligned at a specified known distance with the high temperature medium(v_2) for the verification mechanism for false alarm prevention. The velocity of the wave is estimated in the high temperature medium by using a time delay estimator, which estimates the delay in time (t) taken for the wave to reach the second transducer (T) after it reaches the microphone, which indirectly gives the wave velocity in the medium ($v_2 = x / t$). The data may be fed to an audio Digital Signal Processor which compares the obtained values with preset reference values. Under normal circumstances, the wave velocity remains unchanged from its value when the wave just enters the media, i.e. $\Delta v_1 = (v_1' - v_1) = 0$ and $\Delta v_2 = (v_2' - v_2) = 0$ where v_1' and v_2' are the reference (unchanged) velocity ranges for a normal longitudinal wave in the media as fed into the DSP algorithm. The warning alarm is expected to trigger when the wave characteristics are identified to be altered after its interaction with the media. The signal conditioning circuit compensates for the low amplitude and frequency of the signals by using high gain amplifiers and high order filters.

A simultaneous sensing mechanism could be used for detecting surface vibrations using vibration accelerometer to aid in improving the sensitivity and accuracy of the device and thus, also aiding in detection of landslides, one other catastrophic seismic phenomenon.

Factors that will affect the sensitivity of the device are,

- Material chosen for the ferromagnetic as well as the high temperature medium will affect the rate of change of velocity in the medium.
- Amount of strain on the ferromagnetic material influences the amount of change in the velocity of the wave in the medium at a particular magnetic field.
- The temperature at which the high temperature medium is operated will also influence the efficacy of the verification mechanism and thus, detrimental in the sensitivity of the device.
- The distance between the microphone and the transducer is highly influential in the sensitivity of the medium. If the distance 'x' is large, the velocity change tapped would be significant enough to be measured and processed.
- The sensitivity and type of the vibration accelerometer used will also determine the efficiency of tapping of seismic vibrations.

IV. CONCLUSION

The design of the device is a representation of an innovative approach in construction of an earthquake warning and alert system. The system uses two different subsystems and detects the change in the P wave induced by the subsystems. All sensors used are readily available and cheap thus making it a user friendly and affordable product.

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