Correction for Creeping Wave in Load Cell for Long Term Bio-Metric Data

Rajarshi Banerjee[1] Rajesh Dey[2] Rajkumar Mandal[3] Achintya Das[4]
[1,3]M. Tech. Student [2]Faculty [4]Professor & Head of Dept.
[1,2,3,4]Department of Electronics & Communication Engineering
[1,2,3]SDET-Brainware Group of Institutions, Barasat, Kolkata, India [4]Kalyani Government College of Engineering, Kolkata, India

Abstract— This paper puts forth the author's implementation of a concept which will be able to make the correction of creeping wave effect in sensor. The main concept in this paper is regarding the biometric plantar pressure measurements which are frequently applied for lower extremity injury risk. The different conditions viz., orthopedic liners, footwear and/or physiotherapy activities compared under different exhibits of individuals. The use of biosensors are broadly used in this medical era for efficient monitoring even from remote places. The main problem faced in this techniques is the size of the sensors and the frequency at which the device works. In our case, we have used a load cell to determine the diversion in output corresponding to input. We would proceed first by building a mathematical model on creeping followed by digitizing the output using suiting sampler and A/D convertor. In this scenario, after validating the output, we need to minimize the oscillation produced in the output of creeping effect in load cell by an adaptive technique of modulation. The concept tends to belong to a dynamic process for achieving desired creep compensated response in an adaptive technique using load cell as sensor.

Key words: Creeping, Adaptive Algorithm, Load Cell, Least Mean Square (LMS), Mean Square Error (MSE)

I. Introduction

Load cells are generally used in weighing applications for high accuracy. In a load cell, output will always be proportional to applied pressure. It has been observed that the output from any transducer viz., a load cell changes briskly with respect to time due to creeping error besides the cell is invariant on ideal test condition resulting to an improper data validation in biometric data measurements. As the signal processing system and the control units are not achieving appropriate continuity where erroneous data are picked resulting to low fidelity of sensor response becoming a major restriction in it widespread use of load cells. The accuracy of measurements by cell is affected by certain causes are load factor, environmental forces, interferences with signal transmission, instrumentation and control, creep, hysteresis and non-linearity.

The development of miniaturized, high fidelity, light weight and energy efficient load cells for the application in health care and biometric data collection is an important research focus resulting to technological advance in healthcare monitoring gadgets, fabrication processes and wireless technologies. In this research, creep response have been obtained from the load cell under simulation. Load cell creep is basically the difference between the initial applied pressure to the pressure response at a output. It has been found that the characteristics viz., non-linearity, hysteresis, creeping, temperature effect on zero, all vary over a temperature range of -10°C to 40°C [1].

The restrictions generated in the output response of load cell specially creeping has been studied and simulated with mathematical model. Analog adaptive techniques have been utilized in order to reduce the transient behaviours of the load cell. In some cases, digital adaptive techniques have been proposed in order to utilize the response of the load cell in an effective manner.

Artificial Neural network could also be effective for intelligent data collection and weighing system. Different methods viz., manipulation of Unscented Kalman filter and non-zero initial condition have been employed for dynamic weighing and data collection techniques.

In this work, a new model for Creeping compensation having both positive and an compensating negative region have been mathematically designed followed by a dynamic creeping compensation technique for the erroneous load cell response using an adaptive technique.

II. Related Works

Earlier the adaptive technique is implemented by Mehdi Jafaripanah and Bashir M. Al-Hashimi in their paper 'Application of Analog Adaptive Filters for Dynamic Sensor Compensation' where they suggested analog adaptive technique to the area of dynamic sensor compensation. Stephen C. Stubberud also suggested in his paper 'Online Sensor Modeling Using a Neural Kalman Filter' that the adaptive technique can be provided for online calibration for the sensor models. But the pioneer paper on this field is 'Characterizing the creep response of load cells' by Von R. A. Mitchell and S. M. Baker. In their paper they proposed a search algorithm to solve the nonlinear least square problem for the multiple stiffness and time constants of their suggested model. Pontius and Mitchell showed how the creep is attributable to thermo-elastic effect in their paper 'Inherent Problems in Force Measurement'. A Rheological Model for load cell behaves shown by Mitchell and Baker shows that how a sudden application of force creates drift & creep. All the above works are mainly based on the analog technique.

But in this work, we have introduced an advance technique of adaptive technology is in digitized method in order to obtain an optimized corrected response creeping in load cell. Creeping effect being an restriction in research field, this work has been done to reduce the effect.

III. Mathematical Model

We would demonstrate certain accurate quantitative analysis with the help of a simple experiment. We would regulate a spiral coil clamping at the topmost part to a rectangular cross bar. The lower end would be connected to a point which would point the defined deflection with the help of a scale mixed at some end.

The scale reading would be approximately in the resolution of 1/10th of an inch so that the reading can be read in a gap of 1/5th of an inch. The gap is highly recommended as the reading can be corrected to a readiness of half the inch of the scale [1] [2].

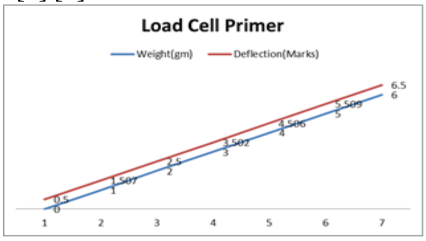

Fig. 1: Load Cell Primer

The graph clearly indicates a algebraic straight line which can be deduced from the mathematical formula

$$D = D_0 + W/k$$

Where, D= Deflection of the spring

D_0=Initial deflection of the Spring

W= Weight of the pan

k= spring constant for stiffness.

The load cell with creeping effect can be mathematically be given where input and gain of the load cell are 'x' and 'g' respectively. This lead as the output of the load cell to be 'ag'. After adding the creeping signal, $\Sigma e^{\pm b} i^{t}$ output of the load cell, we would finally get the equation as [2],

$$\text{Load cell output, } T = g_0 x + \Sigma e^{\pm b} i^{t} \quad (1)$$

Where, T represents the load cell output/response, t represents the time since the force applied, g_0 is the output of the equilibrium and as time t changes, b describes time constant.

The above equation can be explained by a flow chart,

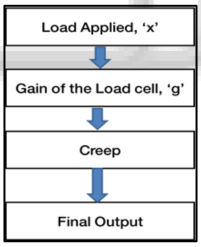

Fig. 1: Output of the load cell due to creep

The creep in the above figure can be demonstrated as $\Sigma e^{\pm b} i^{t}$. The output of the load cell is generally gets contaminated due to creeping effect which is mainly due to the ageing of the load cell. Creeping takes place in two ways, either emergent or crumbling. Depending on the nature of creeping, it is either positive creeping or negative creeping. We would assume an exponential rise or decay where positive exponential rise can be given by $\Sigma e^{+b} i^{t}$ and the negative decay as $\Sigma e^{-b} i^{t}$.

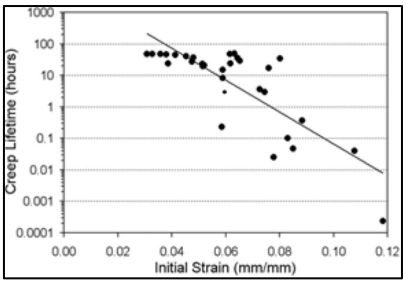

Fig. 3: Creeping of Load cell with initial load

In the figure initial strain is the g_0 as explained in the equation (1). The dots are different states of creeps taken into account at multiple times. The process is explained as the creeping effect of the negative exponential coefficient related to the initial load/strain applied with the gain of the load cell [3].

IV. RECTIFICATION OF LOAD CELL RESPONSE DUE TO CREEPING EFFECT

The creeping effect causes the load cell output to be deviated either increasing exponentially or decreasing exponentially. In order to rectify the creeping effect, we need to add in the upstream for the negative exponential or downstream for the positive exponential response. This is basically done in order to make the output as calculated theoretically. To perform the above task, we need to use an adaptive filter with the help of a sampler to make discreet output of the load cell. This adaptive filter minimizes the creeping effect of the load cell by the process of sampling and quantization. To make the adaptive filter discreet in output, we would assign a weight vector $\vec{v}$ which will be assumed to take all the parameters of the of the adaptive filter. This way we can describe the sequential order of the adaptive filter component $\vec{v}$ as [4]

$$\vec{v} = [\,(h+1)^1 + (h+2)^2 + (h+3)^3 + \ldots]^T \quad (2)$$

The vector component has been designed in such a way as the exponential components rise or decay in the path of sampling and quantization. The sequential output/response has been designed for the purpose of calculating an exponential graph either positive or negative.

The above components of the vector,

$\vec{v} = [(h+1)^1 + (h+2)^2 + (h+3)^3$ can be calculated at different measured values. The value of the vector $\vec{v}$ depend on a unknown time constant which is why the vector can be modified as $\vec{v}(p)$ where p is defined the unknown time constant.

To receive the response with high accuracy, an adaptive technique need to be followed so that the adaptive filter response be in accordance with calculated response. In this regard, Least Mean Square(LMS) can be taken into consideration as this method is simpler to implement [5].

In this way the adaptive method can be utilized to adjust the exponential creeping effect in the load cell response. In this work, we would utilize an adaptive technique with the help of mean square criterion since we have designed the adaptive filter with LMS.

The error signal we receive from the output of the load cell is the input of the adaptive filter with LMS where the output needs to be rectified. Thus the erroneous signal is given as the difference in the calculated response to the received response as

$$E_m = (R * \vec{v}) - Y_m \quad (3)$$

Where,

R= Response of the load cell & input to the adaptive filter to be rectified,

$\vec{v}$= filter vector coefficient

Y_m= Optimized response for R.

By the process of mean square error (MSE) we would minimize the erroneous output with the help of adaptive filter designed [5].

In actual response, the typical tap values are unknown due to fine gain, mismatch in calculated response, feedback constraint and offset errors.

If it is considered that the ADC is ideal then the generated response from sampler + quantizer would typically be $m_k = a^{-k}$ where m_k is response and a is the general adaptive series.

The typical tap values can be simplified using LMS algorithm technique with error signal *e* which is different from E_m by a weighing vector $\hat{P}$

$$e = P_{in} - \hat{P}_{in} \qquad (4)$$

Where $\hat{P}_{in} = W^T P = \sum_{k=1}^{n} a^{n-k} P_k$; $a=2$. (4a)

We can recognize the equation 4a as the weighted code vector $\hat{P}_{in}$.

The least mean square (LMS) algorithm is one of the finest algorithm which in collaboration with MSE gives a great desired response which is actually a semi advanced alternative to remove and reduce the creeping effect from the load cell which is a big challenge in research.

V. Adaptive Filtering Technique

In this work, we have already proposed for an unique approach for designing an adaptive filter with the help of LMS and MSE techniques in order to reduce and minimize the erroneous output. The block diagram for defining the process is given as [6]

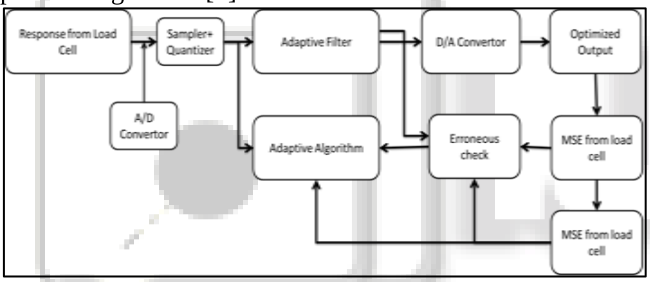

Fig. 4: Flow chart of the process

VI. Simulation Result in MATLAB

The adaptive filter with the LMS have been designed with an adaptive algorithm which minimizes the erroneous response. The response received in the output without the adaptive filter is given as

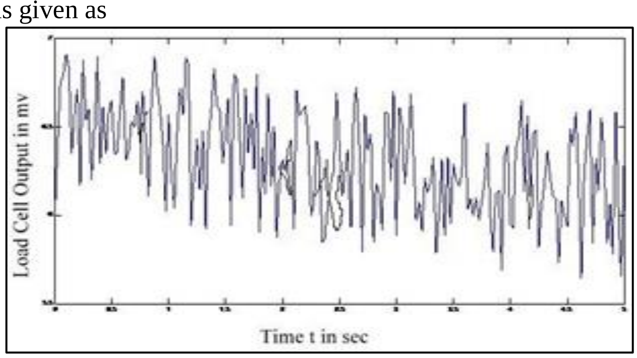

Fig. 5: Simulation Result in MATLAB

As discussed, the load cell response have been sampled with the help of a proper sampler. The output from the sampler is shown as [6]

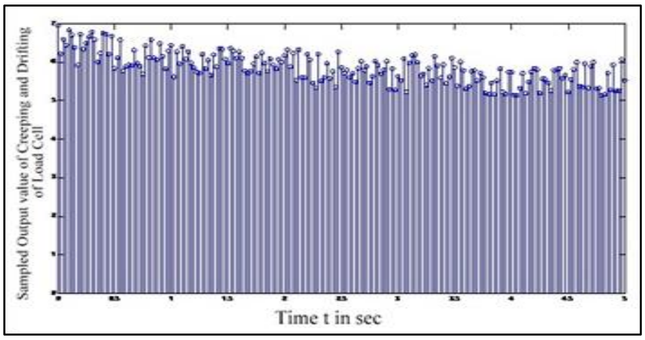

Fig. 6: Simulation Result in MATLAB

After the process of putting the output response of load cell to the adaptive filter, we would get an approximate accuracy with LMS filtering with the calculation of the estimation of error signal *e* followed by the weighted vector $\hat{P}_{in}$. The combination of LMS & MSE gives a combined response which near equal to that of the calculated one the output in the matlab is given as [7] [8]

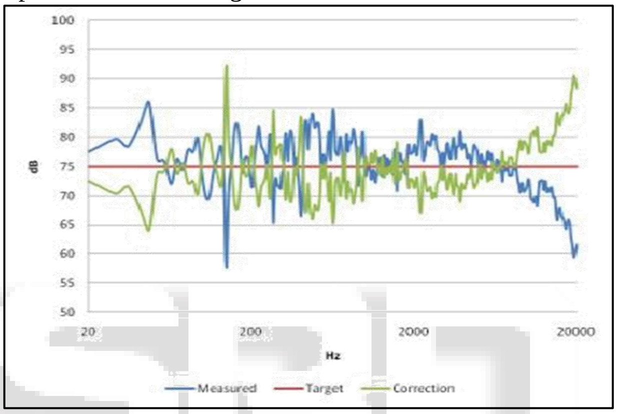

Fig. 7: Load cell response after LMS filtering application

VII. Conclusion

In this research paper, it has been shown and proposed that the output of the load cell can be made non-erroneous with the help of discrete adaptive filtering techniques with the process of LMS and MSE. The same concept is applicable for all other sensors including proximity sensors, accelerometer, etc. The work also shows the various output level of the non-linearity of the sensor which are rectified by adaptive filtering approach. The least mean square algorithm along with the mean square error theorem has been adapted as the process of squaring the mean error actually reduces in quantity which in turn reduces the creeping effect which is the major reason of deviated response of the load cell. The Kalman Filter has given the response to a greater extent of the desired response in the output to the load cell. The practicability has been verified with the help of simulations under matlab and tanner tool. The adaptive filtering technique can be improved more with the help of upcoming technologies. The implementation of the hardware is in the process of research and will be completed in near future.

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