Correction of Load Cell Response using Mathematical approximation

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Abstract

Mechanical force can easily be converted into electrical signal by load cell. But the response becomes noisy due to the presence of nonlinearities. This response needs to be rectified to get a appropriate result. A technique of active rectification of load cell output using mathematical approximation like Particle Swarm Optimization (PSO)

is offered in this research article. PSO is a mathematical approximation method that applies a data set as its exploration space and searching for the optimized result The present move toward approximation of a load cell response according to the mean value of the input data. The approximation algorithm converges to set response near to the best value

Keywords: *Damper System, Load cell, Mass Spring Damper (MSD), Particle Swarm Optimization (PSO)*

1. Introduction

Load cells are applied in a variety of measuring device in aerospace, health & automation etc.The settling time of load cell is extended and over damped; so response of load cell is noisy due to extended transient behavior. Instrumentation &measurement engineering cannot function properly if input data is fallacious so compensation of the insufficiency of proper response is major difficulty in research [1, 2].

An oscillatory response of sensor takes longer time to settle down. Self-adjusted computation method applied to the detect the final value. As a result it is necessary to activate the value of the input in the best time probable to increase speed of the procedure of measurement.. One model can be applied on the sensor response is filtering to accomplish best measurement [2].

Rectification of Erroneous output of sensor is a extensively used topic for research. A number of techniques are in use to uncover the result [3]. The paper Described software compensation techniques based on software. Rectification method using Adaptive algorithm are explained in [2, 4]. Digital signal processing using adaptive control have been explained in [5]. Neural network can be applied to rectify nonlinearities in weighing systems [6, 7]. Kalman filtering with initial value may be used for rectifying weighing systems [8, 9].

In this article, a Particle Swarm Optimization method is applied for active rectification of load cell nonlinearities Section II presents Particle Swarm Optimization and its structures. In next step mathematical model of sensor & rectification process has been discussed.

2. Mathematical optimization

Particle Swarm Optimization is based on sample population & stochastic optimization method.The solution is achieved with knowledge of random mathematics and finds optimum data by modifying variables. Particle Swarm Optimization can easily be applied with inexpensive hardware .

During application, the samples modify velocity components and sample space based on optimum data of population . The methods are depicted in [13].

1. Space & Velocity of data sets are within known domain.

2. , the above mentioned variable of all sample particles are modified(in each iteration)-).

$$u(t+1) = w \times u(t) + l_1 \times f_1 \times (s_{best} - s(t)) + l_2 \times f_2 \times (global_{best} - s(t)) \quad (1)$$

s(t) and u(t) -present space and velocity of sample population. The s_{best} is the space with optimized value and $global_{best}$ is the best approximated value present in data set or population.

3. The space of the data population is also modified as stated (2).

$$s(t+1) = s(t) + u(t+1) \quad (2)$$

3. Nonlinearity Model of Load cell

Many methods are used to explain nonlinearities in sensor. Nonlinearity model of the load cell can be shown as a Mass Spring Damper model of control engineering. ‘w’ is mass to be measured & W is the load cell weight with spring constant l. When Mechanical force is subjected to the load cell, a opposite force is developed $f_{spring} = -l \times x$.

Eequilibrium equation of load cell depends on damping coefficient. Damping force depends on the damping parameter z; $f_{Damping} = -z$, where z is the damping parameter. Now Force equilibrium is shown in equation(3).

$$(W+w)\frac{d^2x}{dt^2} + z\frac{dx}{dt} + lx = f \quad (3)$$

3.1. Nonlinearity model using Average settling time

Here it is assumed that every sensor response has enough settling time. But in practical there is a presence of transient in response.

3.2. Nonlinearity model using rearranging Frequency Method

The technique designated in this unit has been entitled as the frequency method as the unidentified weight is projected by reorganizing the frequency equation in (4).

$$Frequency = \frac{1}{2}\sqrt{\frac{4z(W+w) - z^2}{(W+w)^2}} \quad \text{.............................. (4)}$$

Every sensor has its own characteristics. It is needed to calculate mechanical equivalent parameter. The inherent parameter W z and l are calculated. Then the mass can be measured, using above mentioned parameters, by taking the value of the first two successive amplitude The angular frequency can be measured as shown in equation (5).

$$w = \frac{z + \sqrt{z^2 - \left(\frac{2\pi}{(t_2 - t_1)}\right)^2 l^2}}{2\left(\frac{2\pi}{(t_2 - t_1)}\right)^2} - W \quad (5)$$

3.3. Damping nonlinearity Method

In view of the nonlinearity model of sensor unknown weight is approximated by reordering the damping coefficient shown in equation (6).

$$z = \frac{l}{2(W+w)} \qquad (6)$$

4. Load Cell Response Rectification

The Gain of a sensor is taken as G(s). It is identified that damping present in response of sensor as already described in previous discussion. The electrical parameter of load cell alters when a mechanical force is subjected to it; since load cell mass gives additional damping to the electrical behavior of the system. So, the gain of the filtering system should be substituted similarly. Previous research has shown that mathematical model of load cell can be specified by second order differential equation [3],

$$(W+w)\frac{d^2x}{dt^2} + z\frac{dx}{dt} + lx = f \qquad (7)$$

Where w is taken as applied the mass, W is the sensor mass, z is taken as damping factor, l is taken as spring constant, and f(t) is the resultant force . Here, the sensor mass has been neglected. Thus gain is specified in algebraic equation in Laplace form (8).

$$G(s) = \frac{Y(s)}{f(s)} = \frac{1}{ws^2} + zs + l \qquad (8)$$

So the load cell response with nonlinearities are over- damped or under damped behavior like as shown in figure 2.

As a part of rectification first the signal is sampled and a mean value of the response is approximated and means value is taken as an optimized value for the Particle Swarm Optimization to approximate the algebraic equation [14]. The mean value 0.2 is intended so as to fit Particle Swarm Optimization as global optimized value. Input in Particle Swarm Optimization variant does not comprises the local best value of the velocity changing mathematics. It also solving mathematics with the global best value henceforth we have modified solving method which is as follows in equation (9).

$$y(t+1) = wv(t) + zf\,(mean_{best} - p(t)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (9)$$

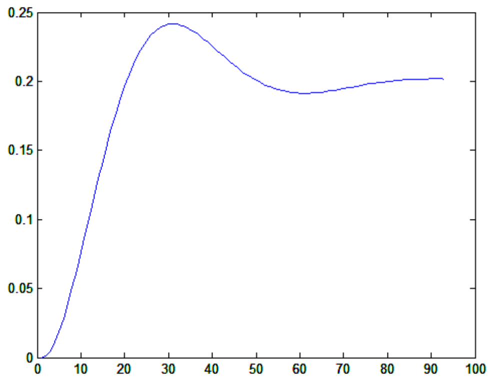

Figure 2. Output of a Load Cell with Transients

So the $mean_{best}$ is the mean value. Next, the optimization is applied to rectify response of the load cell. The rectified response is shown in figure 3, figure 4, and figure 5, but with different parameter value.

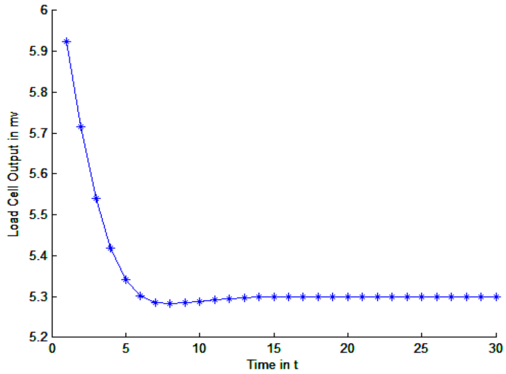

Figure 3. Rectified Load Cell Response with z = 0.2

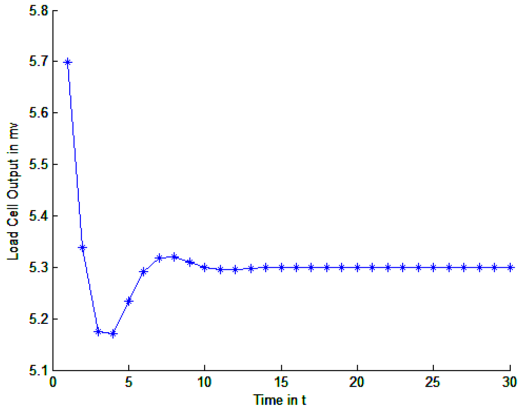

Figure 4. Rectified Load Cell Response with z=0.5

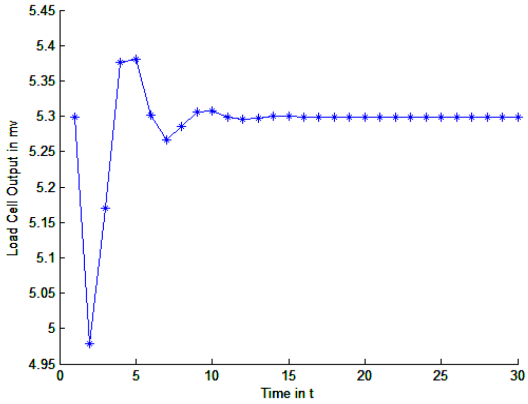

Figure 5. Rectified Load Cell Response with z = 1

5. Conclusion

Mathematical approximation based method is presented in the article. The PSO is selected for its simpler application compared to other approximation techniques . Here the mathematics behind the optimization process enhance the processing time to provide a desired response to a real time response.

a global best PSO algorithm is used to rectify nonlinearities in response.The results from mathematical approximation based optimization shown in the simulations are perfect.

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