Correction of Load Cell Output using Particle Swarm Optimization

Banashree Debnath, Indranil Sarkar, Srabanti Chakraborty, Rajesh Dey, Sandip Roy

Abstract**:** ***A load cell is a type of force transducers that transform force and mechanical stress into electrical signal. But the output becomes distorted due to the presence of transient response. Particle Swarm Optimization (PSO) based correction of load cell output is presented this paper. PSO is a robust stochastic optimization technique that considers a swarm of particle (data) as its search space and looks for the best solution. The current approach optimizes a load cell output based on the median value of the signal. The optimization algorithm tries to bring the output response near to the median value.***

Keywords: Artificial Neural Network (ANN), Damper System, Mass Spring Damper (MSD).

I. INTRODUCTION

There are various weighting applications such as vending machine, automatic check – weighing system, vending machine, etc. where load cells are used and the weight measured by these cells are distorted by a transient response because the settling time of these load cells is highly long and damp. Due to this control system and signal processing cannot work properly if they collect erroneous data. There are some major drawbacks in current research such as parameter drift, cross-sensitivity, and nonlinearity [1, 2].

It is to be noted that sensors always have an oscillatory response which demands to settle down. When the ending assesses of a load signal is detected through dynamic computation and its result is at slowdown in oscillation. Thus in some applications, it is demand to operate the measured value in the quick time feasible to speed up the operation of assessment. For example, the sensor output signal is filtering reach response improvement [2].

Imperfection in the sensor output is a widely researched topic and a lot of literatures are present. A number of approaches are taken to find the solution to the problems [3].

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Deals with software based compensation techniques. Adaptive techniques are surveyed in [2, 4].

In the research paper [5], authors have proposed a digital adaptive algorithm. Authors have discussed about ANN for smart weighing systems [6, 7]. In [8, 9], the authors explained

the application of dynamic weighing using a Kalman filter and nonzero initial condition.

In this paper, a PSO based optimization approach is taken for dynamic compensation of load cell response. Section II introduces the basic PSO algorithm and its features. The mathematical modeling of load cell has been discussed in section III. In Section IV, introduces the approach to optimize the load cell output. Section VI includes conclusion and future works.

II. PARTICLE SWARM OPTIMIZATION (PSO)

PSO is a population based robust algorithm for solving continuous and discrete optimization problem. PSO can be easily implemented and is computationally inexpensive. In the PSO algorithm, all the particles update its own velocity and position based on (1). The detail steps of the PSO algorithm are discussed in [13].

1) Initially, all the particles are randomly set the velocity *v(t)*, position *p* within predefined ranges and current position is *p(t)*.
2) The velocities of all particles are updated using (1). The best objective value of the position is p_{best}.

$$v(t+1) = w \times v(t) + c_1 \times R_1 \times (p_{best} - p(t)) + c_2 \times R_2 \times (g_{best} - p(t)) \quad (1)$$

3) The position of the particle is also updated using (2).

$$p(t+1) = p(t) + v(t+1) \quad (2)$$

III. MATHEMATICAL MODEL

There are three types of methods such as “Average Method”, “Frequency Method”, and “Damping Method” are required to differentiate and explore for gauging of weight of different types of items. The load cell model as “Mass Spring Damper (MSD)” system is presented in Fig 1. The spring constant is *k*, where equivalent mass *M* is attached to a mass-less spring. A counteracting force is resulted when a load is supplied to the load cell. This spring force presented by the Hooke’s law stated $f_s = -k \times x$.

Now, notice the impairment of the damping factor in dynamic balance feature rather it is sufficient to model in fixed balance feature of the load cell.

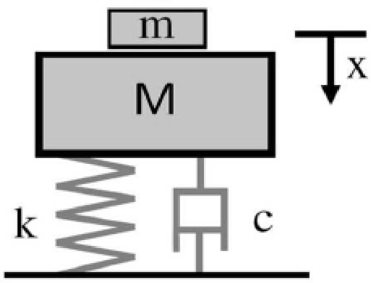

Fig. 1. Damper System.

For the dynamic feature, Viscous damping method is assumed and defined by $f_D = -c$, where the damping force is proportionate with the velocity. Equation (3) using Newton Second Law of motion.

$$(M+m)\frac{d^2x}{dt^2}+c\frac{dx}{dt}+kx=R \tag{3}$$

While load cell result is not represented by any measure, a changing part requires to be calculated. Thus the new equation can be presented in (4).

$$x=\alpha\left(c_1e^{-\mu t}\cos(\omega t)+c_2e^{-\mu t}\sin(\omega t)+\frac{(M+m)}{k}\right) \tag{4}$$

Where c_1, c_2 are constants, μ is the damping factor, and α is a conversion factor.

A. Averaging Method

It has already assumed that oscillatory reaction has sufficient settling time for load cell modeling method.

B. Frequency Method

In this method, the unknown mass is predicted by repositioning the frequency in (5).

$$\omega=\frac{1}{2}\sqrt{\frac{4k(M+m)-c^2}{(M+m)^2}} \tag{5}$$

Though each load cell is property wise distinctive, so the parameters of every load cell, such as damping co-efficient *c*, spring constant *k*, and mass *M* are required to calculate only once. After measuring the first two successive peaks. Fig. 2 and Fig. 3 have shown the outputs of the load cell.

In the given equation (6), the difference between the two successive peaks is required for assessing the circular frequency *ω*.

$$m=\frac{k+\sqrt{k^2-\left(\frac{2\pi}{(t_2-t_1)}\right)^2c^2}}{2\left(\frac{2\pi}{(t_2-t_1)}\right)^2}-M \tag{6}$$

C. Damping Method

Fig 1 is represented the model of the load cell system. The damping factor equation is presented in (7).

$$\mu=\frac{c}{2(M+m)} \tag{7}$$

IV. LOAD CELL RESPONSE RECTIFICATION

In the introduction section, it has lucidly discussed that naturally, any sensor output is damping, transient and also the steady-state phase of responses. The below second-order system can be represented in (8) [3].

$$(M+m)\frac{d^2x}{dt^2}+c\frac{dx}{dt}+kx=R \tag{8}$$

Where the effective mass *m* is being measured, the damping factor is presented by *c*, and the force function is represented by *R(t)*. Equation (9) presents the transfer function.

$$G(s)=\frac{Y(s)}{R(s)}=\frac{1}{ms^2}+cs+k \tag{9}$$

So the output of a load cell with transient response will look like as shown in Fig. 2. As a next step the signal is sampled and a median value of the signal is calculated and median value as a best value for the PSO to optimize the equation [14, 15]. The median value 0.1989 is calculated so as to feed the PSO algorithm as global best value. The PSO variant which we worked with does not contains the local best part of the velocity update equation. It works with the global best part hence we have applied equation which is as follows in (10).

$$y(t+1)=wv(t)+cR(g_{best}-p(t)) \tag{10}$$

So the g_{best} is the median value. Next, the algorithm is run and it optimizes the output of the load cell and a compensated output is shown Fig. 3, 4 and 5.

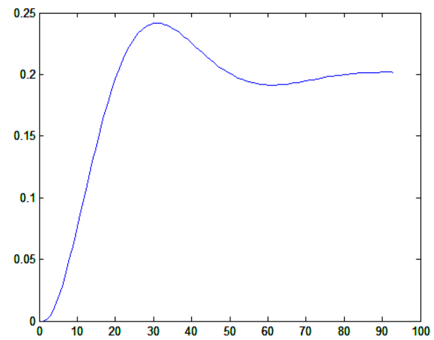

Fig. 2. Output of a Load Cell with Transients.

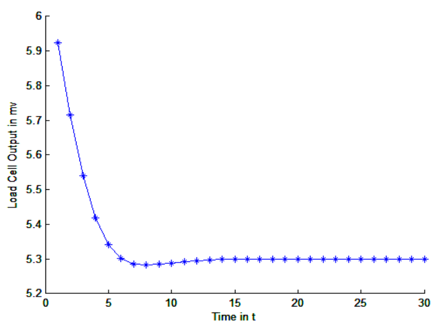

Fig. 3.Compensate Load Cell Output with c = 0.22.

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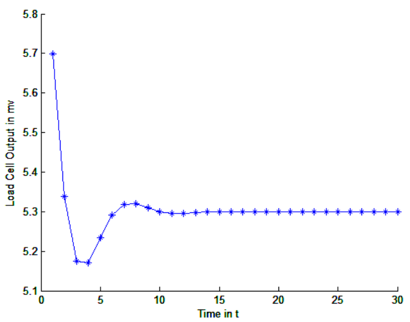

Fig. 4.Compensate Load Cell Output with c = 0.5.

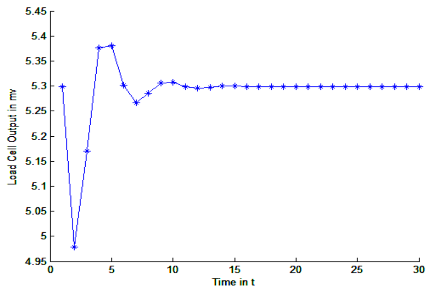

Fig. 5.Compensate Load Cell Output with c = 1.

Table 1. Load cell output analysis

Time	Load Cell Output in mv		
	c = 0.22	*c = 0.5*	*c = 1*
5	5.34	5.25	5.38
10	5.31	5.31	5.32
15	5.32	5.30	5.31
20	5.30	5.30	5.31
25	5.30	5.30	5.31
30	5.30	5.30	5.31

In table 1 and fig. 3, 4 and 5, it is lucidly explained the load cell output. Our results show that the settling time of these load cells is stable with different damping factors c = 0.22, 0.5 and 1. Here, we have used Particle Swarm Optimization (PSO) for its simplicity and the optimization outputs shown in the simulations are acceptable.

V. CONCLUSION

An optimization based approach is taken in the work presented in the paper. The PSO is chosen for its simplicity of application over other optimization methods like the Genetic Algorithm. Here the complexity of the optimization algorithm would add to the time to give a corrected output to a real time response. Hence a lighter algorithm is preferred. Here we have used a global best based PSO algorithm, called social only model. The optimization results shown in the simulations are satisfactory.

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