SIMPLIFIED MODEL OF MASS MEASUREMENT SYSTEM WITH CONSIDERATION OF VARIATION OF FULCRUM POSITION

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Abstract:

This paper focuses on an analysis of behaviour of a dynamic mass measurement system. The goal of this paper is to propose a dynamic model of the system, which can reproduce dynamic behaviour to floor vibration. The dynamics of our system with electro-magnetic force compensation is approximated by a mass-spring-damper system, and an equation of motion is obtained. Model parameters are also estimated from experimental data. Then, comparisons of the proposed model with the previous model are carried out, and the effectiveness is also confirmed.

Keywords: checkweigher; mass measurement; dynamic model; floor vibration

1. INTRODUCTION

Checkweighers are systems that can measure the mass of a target object continuously while conveying the object on a belt conveyor. The checkweighers has operating an active role in various fields. Recently, research on a dynamic mass measurement rather than a conventional static mass measurement has been done actively, and some related studies have also been performed. To achieve the dynamic mass measurement with high accuracy contributes to the continuous mass measurement. In the dynamic mass measurement, however, there exists a problem that a disturbance such as a floor vibration affects an accuracy of the mass measurement strongly. In fact, although load cells have been used to measure the mass of the object in the checkweigher, the measurement accuracy is susceptible to environmental effect (floor vibration) due to the structure of the load cells. To solve this problem, some research has been performed [1], [2], [3], [4].

As the first step to this problem, we propose a dynamic model of our mass measurement system in this paper. In particular, we consider a variation of fulcrum position to the dynamic model in our system, compare the new model with the previous one, and confirm an effectiveness of the proposed model of our mass measurement system. By using the dynamic model, we expect to decrease the effect of the floor vibration.

2. MEASUREMENT SYSTEM

This section explains the system structure and modelling of our mass measurement system as shown in Figure 1.

2.1. System structure

Our mass measurement system is composed of weighing platform, the Roberval mechanism, the lever linked Roberval mechanism, the counterweight, the electromagnetic force actuator, and the displacement sensor. By applying the Roberval mechanism to the measurement mechanism, the mass of the object can be measured appropriately wherever the object is located on the weighing platform. The mass of the object is estimated from the input (current or voltage) to the electromagnetic force actuator that controls the lever displacement.

2.2. System modelling

Figure 2 shows a physical model of the mass measurement system. In the physical model, we newly considered a displacement of a fulcrum point due to a floor vibration. By adding this element, we can evaluate the effect of the floor vibration on the mass measurement system accurately. Moreover, we will contribute to suppress the effect of the floor vibration when the mass of the object is estimated in the system.

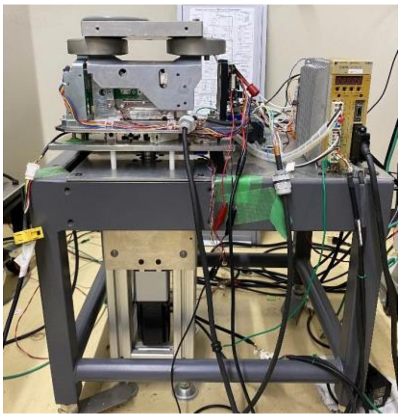


Figure 1: Photograph of mass measurement system

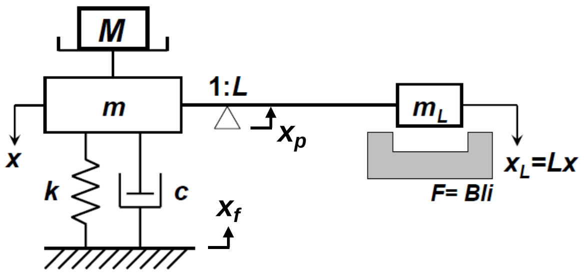


Figure 2: Physical model

For the physical model shown in Figure 2, an equation of motion about mass m of the Roberval mechanism can be derived from equation (1).

$$(M+m+m_\mathrm{L}L^2)\ddot{x}+c\dot{x}+kx=Mg+FL+c\dot{x}_\mathrm{f}+kx_\mathrm{f} \quad (1)$$

where M is mass of an object to be measured, c a damping coefficient, k a spring constant, m_L mass of the lever, L (= 20 (= m/m_L)) the lever ratio, x the displacement of mass m, g (= 9.8 m/s^2) the acceleration of gravity and F ($=Bli$, where B is magnetic flux density, l coil length, and i current) an electromagnetic force which means the control input in order to control the position x_L of the lever, and x_f an amplitude of the floor vibration.

From equation (1), the natural frequency f of the measurement system can be given by equation (2)

$$f=\frac{1}{2\pi}\sqrt{\frac{k}{M+m+m_\mathrm{L}L^2}}\,. \quad (2)$$

From the experimental result, the natural frequency f and damping ratio are 5 Hz and 0.08, respectively. Thus, the spring constant k can be calculated from equation (1). Also, the damping coefficient c can be adjusted so as to match the convergence rate in the realistic responses of the system. Taking the displacement x_p of the fulcrum position into account, the displacement of the lever x_L can be given by equation (3)

$$x_\mathrm{L}=-L\left(x-x_\mathrm{p}\right). \quad (3)$$

In this paper, we assume that the displacement x_p of the fulcrum position is given by equation (4)

$$x_\mathrm{p}=Xx_\mathrm{f}\,, \quad (4)$$

where X is a parameter for duplicating the displacement of the fulcrum position.

3. RESULTS

3.1. Simulation results

To evaluate the validity of the proposed model as described in Section 2.2, we compared the proposed model (X = 0.98) with the previous model (X = 0.00) in simulation. Figure 3 and Figure 4 show the simulation results for the floor vibration with an acceleration of 0.789 m/s^2 and a frequency of 12 Hz. From this result, we confirmed that the proposed model can reproduce the dynamic behaviour under the floor vibration situation. In particular, the response in the previous model (Figure 3) is unstable, but the proposed model (Figure 4) is stable.

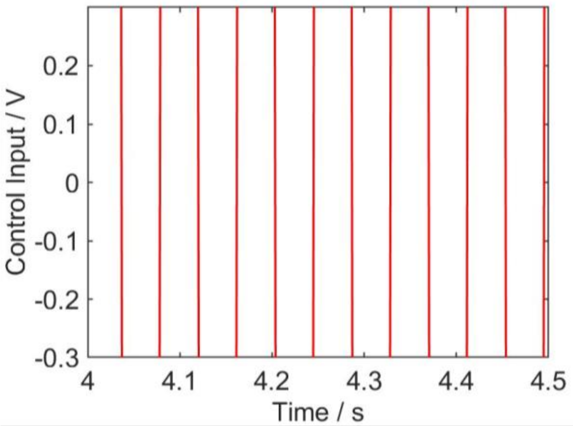


Figure 3: Simulation result in case of X = 0.00

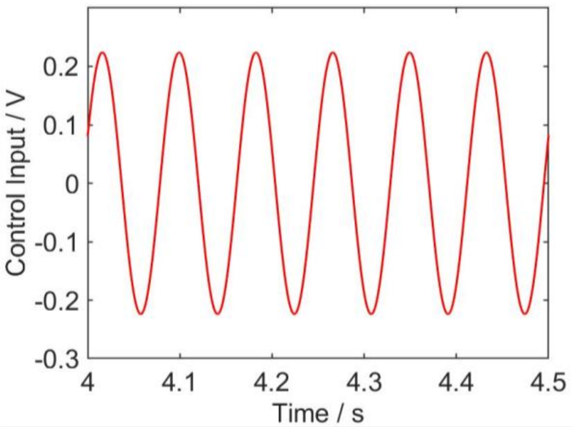
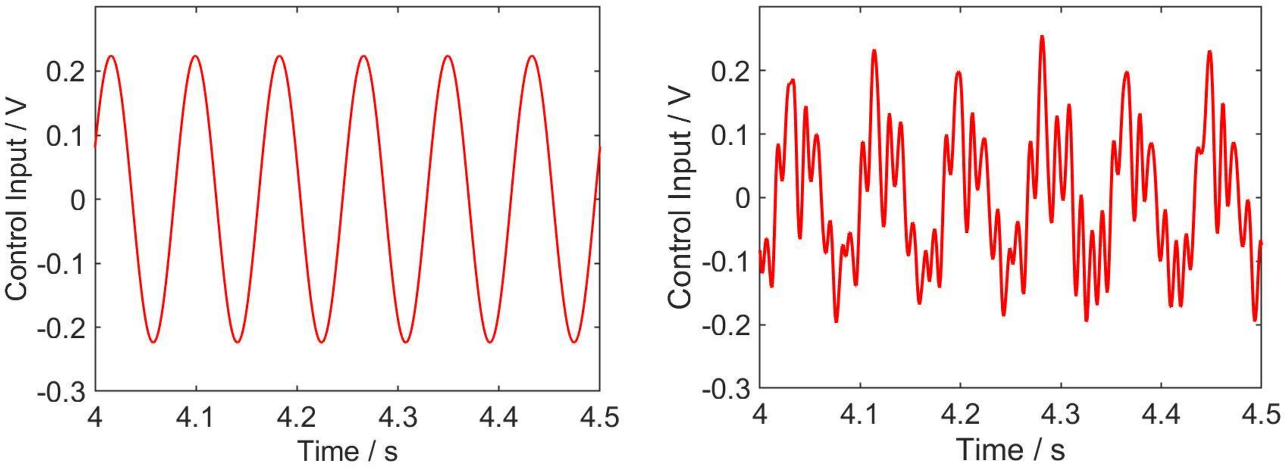


Figure 4: Simulation result in case of X = 0.98

3.2. Experimental results

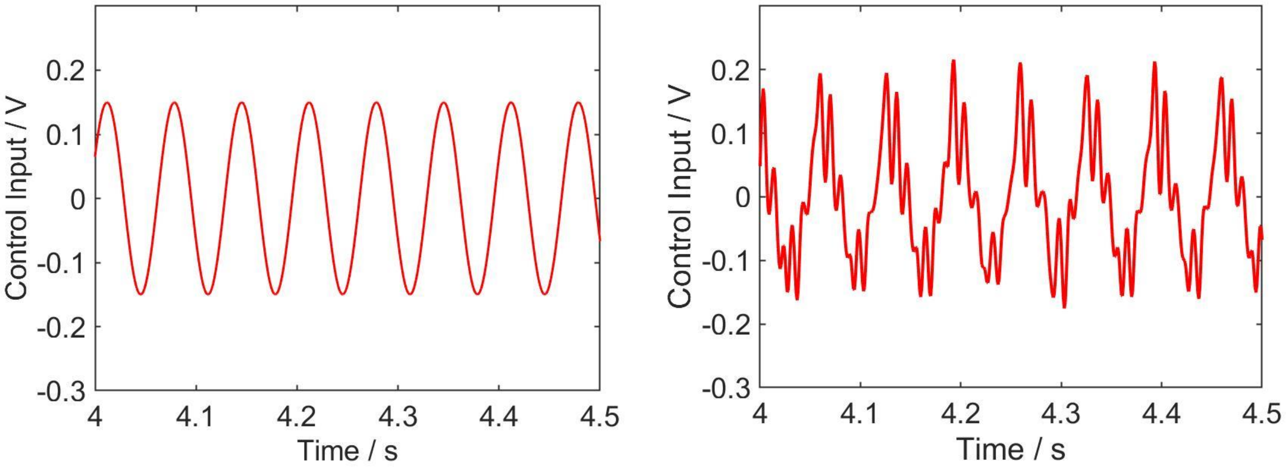
Next we show comparison results of experiment and simulation using the proposed model. For the experiment, we have manufactured the vibration exciter that can reproduce environmental vibration such as a floor vibration [5]. The experimental condition is as follows; the acceleration of 0.789 m/s^2 (constant) and the frequency of 12 Hz, 15 Hz, and 18 Hz. Here the amplitude is adjusted so as to keep the acceleration of 0.789 m/s^2.

Figure 5 shows the output ($F=V$) of the mass measurement system in case that the frequencies equal to 12 Hz, 15 Hz, and 18 Hz. It can be seen from Figure 5 that the duplication of the response to the floor vibration is realised. However, the amplitude is a slight difference between the simulation and experiment at 18 Hz (Figure 5(c)). Moreover, the higher vibration than the floor occurred in the experimental result. For these problems, we will improve the simulation model and experimental environment.



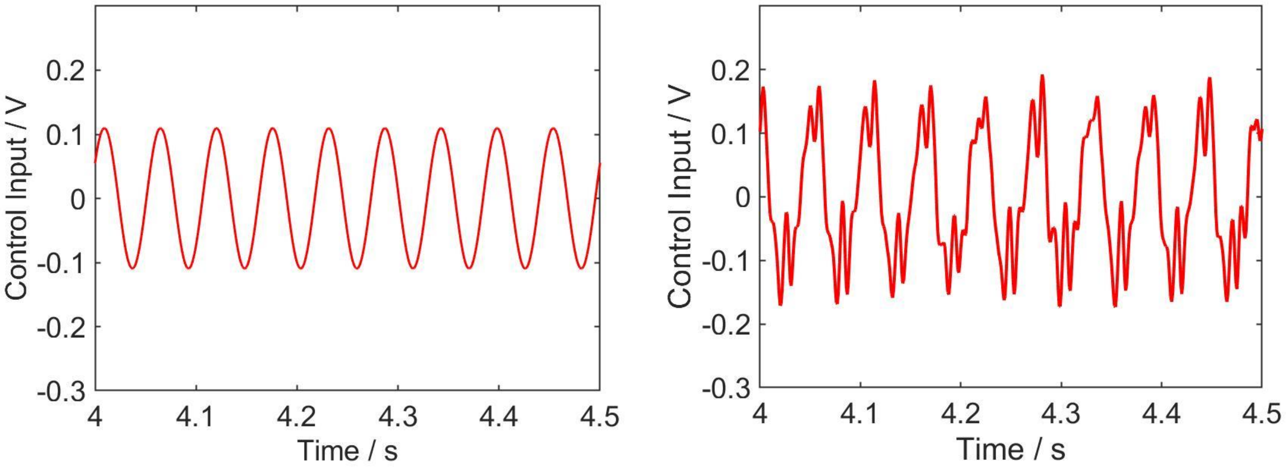
(a-1) Simulation (a-2) Experiment

(a) 12 Hz



(b-1) Simulation (b-2) Experiment

(b) 15 Hz



(c-1) Simulation (c-2) Experiment

(c) 18 Hz

Figure 5: Simulation and experiment results

4. SUMMARY

We proposed a new model of our mass measurement system to duplicate dynamic behaviour of the system under the floor vibration. In particular, we newly considered and added a displacement of a fulcrum position to the model. Comparing the proposed model with the previous one, we confirmed the validity of the proposed model under the condition of floor vibration. Also, we confirmed the effectiveness of the proposed model by comparison the simulation with the experimental result. As a result, we can conclude that the proposed model contributes to analyse and solve the effect of the floor vibration.

5. REFERENCES

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