A Proposal of Dynamic Scales for Measuring the Mass of Agricultural Products

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Abstract. The rapid development of agricultural products industry in Indonesia presents a new challenge for the industry. The high demand for agricultural products makes the industry must think to manage the plantations more effectively and efficiently. One of the problems in plantations is the process and procedure of weighing agricultural products. At this time the process of weighing agricultural products takes a long time and a long procedure. In the industry, processes and procedures for weighing agricultural products as they are today being considered inefficient. Direct weighing at the time of collection is assessed to be rapid and highly beneficial to the industry. But there is a problem when weighing is done directly. If weighing is done directly at the time of collection, then the weighing is done under dynamic conditions. To be able to solve the problems in weighing the agricultural products then proposed a study to build a dynamic weighing system that can weigh dynamically where direct weighing agricultural products can be done at the time of collection. The force transducer will measure the force applied by the weighing system and the load in the form of industrial products. Because the system works in a dynamic state, the forces acting on the force transducer can be calculated using Newton's second law \( F = (m_a + m_k) \cdot a \) and \( m_k = \frac{F}{a} - m \), where \( a \) is the deformation acceleration of the force transducer which is proportional to the acceleration of the weighing system, \( m_a \) is the mass of the weighted system supported by the force transducer and \( m_k \) is the mass of the product being weighed. The deformation acceleration of this force transducer is measured using a flat coil.

1. Introduction

Currently, the available weighing method is the static weighing method. When the load is placed on a static (fixed) scale, the mass of the load is measured once the balance is stable. In digital scales, force transducers are generally used as sensors. The weighing procedures generally applied in industry are static weighing consisting of weighing transport trucks containing agricultural products, then weighing the mass of empty trucks. So we get the net weight of agricultural products on the truck. To improve the efficiency and effectiveness of processing agricultural products, we need a scale that can measure the weight / mass of agricultural products directly when agricultural products are moved. These scales are called dynamic scales. There is currently no dynamic weighing method or instrumentation for dynamic weighing [1].

Conventional digital scales typically use force transducers as sensors. However, the current force sensor has not been dynamically calibrated and therefore cannot be used to measure dynamic force.
and dynamically weigh mass. Force transducers are typically statically calibrated using static load[2]. At present, there is no adequate standard method for dynamic calibration of force sensors[3].

Several methods have been developed to dynamically calibrate force transducers. This method uses the force of inertia of the mass placed on the force transducer, this inertia force is produced by the shaker[4–6]. In this method, the shaker will shake the mass and force transducer to be calibrated continuously and dynamic forces with a single frequency will be generated and worked on the force transducer. This method will be effective in evaluating the characteristics of force transducers under the conditions under which calibration is performed, such as continuous vibration conditions with a single frequency. However, this method is not suitable for use in evaluating the force transfer response of the force transducer which is very necessary for the measurement of dynamic forces, particularly impact forces.

In this study, a dynamic mass measurement system using a force transducer and a distance sensor based on a flat coil was proposed. The research on the flat coil that we made previously resulted in several patents[7–11] and publication[12–18]. In the dynamic measurement system that we are going to develop, we need dynamic error correction. This dynamic error correction is performed using an optical interferometer based on the LMM (Levitation Mass Method)[19].

Proposed research to produce dynamic weighing system offers good business prospects. This scale will be very beneficial for agriculture, fisheries and other. This system promises a direct, fast and accurate weighing method.

2. The principle of proposed system
The scales system to be developed can be seen in Figure 1. The force transducer will measure the force applied by the weighing system and the load of agricultural products. Since the system operates in a dynamic state, the forces acting on the force transducer can be calculated using Newton's second law.

![Figure 1. The proposed dynamic scales](image)

From Newton's second law:

\[ F = (m_i + m_k) \cdot a \] (1)
Where $a$ is the acceleration of the deformation of the force transducer which is proportional to the acceleration of the weighing system with a load of agricultural products, $m_t$ is the mass of the weighing system supported by a force transducer and $m_k$ is the mass of agricultural products weighed.

The acceleration of the deformation of this force sensor is measured using the flat coil that we developed previously. The details of this system are illustrated in Figure 2.

The force applied by the weighing system and the mass of the load (agricultural products) on the force sensor will cause a deformation of the force sensor, then the force acting on the force transducer will be measured. Because the system is moving and the weighing is done dynamically, the system and the weighed load (agricultural products) cause a deformation of the dynamic force sensor that is proportional to the acceleration of the system. To be able to measure the acceleration of the deformation (acceleration of the system), a flat coil sensor is used. Figure 3 shows the design of the flat coil used.

The basic principle of the flat coil sensor work is to measure the change in distance between the mass of the paramagnetic material and the flat coil. The flat coil will move with the deformation of the

$$m_k = \left(\frac{F}{a}\right) - m_t$$

(2)
force transducer due to the forces acting on it. Changes in the distance due to the movement of the flat coil cause changes in the induction flux on the flat coil element, resulting in a different inductance for each given distance [16]. This inductance will be measured by an oscillator whose parts are on a flat coil and partly on an electronic circuit. This inductance is then processed in the electronic signal processing circuit contained in the printed circuit to produce a voltage which represents the changes in distance, then an acceleration can be deduced from the changes of this distance.

Due to the change in distance from the flat coil to the intruder's mass, the greater the distance, the lower the inductance and vice versa. With the inductance change on this flat coil, this flat coil can be used as an inductor to form an oscillator by adding a capacitor[14]. This oscillator consists of a flat coil acting as inductance and a capacitor whose components are capacitors mounted on an electronic signal processing circuit. If the inductance of the flat coil changes, the frequency of the oscillator signal will also change. Thus, the function of the oscillator is to transform the inductance change into a voltage signal whose frequency depends on the change of inductance in the flat coil. The output of the oscillator is a sinusoidal frequency analog voltage.

3. Discussion
To make accurate measurements, the dynamic weighing system is first corrected using an optical interferometer system [19] with dynamic force measurement error by force sensor expressed as:

$$F_{\text{diff}} = C \cdot \frac{d^2 F}{dt^2}$$

Then error $F_{\text{diff}}$ estimated using the second derivative of the scale exit system as a function of time, with $C$ is a constant (correction factor). Then, the actual force (the corrected force) acting on the weighing system is

$$F_{\text{corrected}} = F_{\text{trans}} - F_{\text{diff}}$$

The force transducer will measure the force applied by the weighing system and the load of agricultural products. Since the system operates in a dynamic state, the forces acting on the force sensor can be calculated using Newton's second law. From Newton's second law:

$$F_{\text{corrected}} \propto (m_i + m_k) \cdot a$$

$$F_{\text{corrected}} = k \cdot (m_i + m_k) \cdot a$$

where $a$ is the acceleration of the deformation of the force transducer which is proportional to the acceleration of the weighing system with a load of agricultural products, $m_i$ is the mass of the weighing system supported by a force sensor and $m_k$ is the mass of agricultural products weighed. The acceleration of the deformation of this force sensor is measured using a flat coil, as shown in figure 3. To obtain the correction factor $k$ then measurements are taken with $m_i$ and $m_k$ that already known. So

$$k = \frac{F_{\text{corrected}}}{a \cdot (m_i + m_k)}$$

by knowing $k$ then scales can measure $m_k$ dynamically.

Figures 4 and 5 are graphs of preliminary experimental results of the dynamic scale system developed. Figure 4 shows that there is a similarity of the pattern between the measurement error of the dynamic scales and the acceleration of the scales when taking measurements.
Figure 4. Similarity of the pattern between the measurement error of the dynamic scales and the acceleration of the scales.

In this experiment, the acceleration of the weighing system is measured using an accelerometer. To determine the relationship between acceleration and dynamic mass measurement errors using the weighing system, the data in Figure 4 are plotted to obtain the effect of acceleration on the measurement errors of mass. Figure 5 shows that there is a linear relation between the acceleration and the measurement error, so that the measurement error of the dynamic mass measurement by the scales can be corrected by estimating the error as a function of the acceleration.

Figure 5. Relation between the acceleration and the measurement error.

4. Conclusions
A dynamicscales for measuring the mass of agricultural products has been proposed. In this dynamic scales, Force transducers are used to measure the force applied by the weighing system and the load in the form of agricultural products. The force acting on the force transducer can be calculated using Newton's second law because the system operates in a dynamic state and the acceleration of the deformation of the force sensor is measured using a flat coil. From the preliminary experimental results, we obtained a linear relation between the acceleration of the scale system and the dynamic
scale measurement errors, so that the mass measurement errors obtained by dynamic scales can be corrected by estimating errors as a function of acceleration.

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Acknowledgment
This research was supported by funding from ‘HibahDesentralisasi Program Penelitian TerapanUnggulanPerguruan Tinggi’ (PTUPT) of the Indonesian Ministry of Research, Technology and Higher Education (Decree Number 6/E/KPT/2019 and agreement/contract number 2/E1/KP.PTNBH/2019).