Dynamic behavior of mass measurement system using load-cell (2nd report) -Effect of partial load distribution-

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Abstract. Check-weigher using a load cell type scale is a device that measures while conveying the mass of an object to be measured. In general, load cell type scales are used stationary state, but in check-weigher, it is necessary to estimate the mass value before the scale is balance still in order to high performance. Moreover, a conveying motor is necessary in the configuration of apparatus, and this mass affects the measured value of the scale and the measuring time. In this study, a dummy conveyor was manufactured giving the mass of the motor as unbalanced load. As a result of static and dynamic analysis for the dummy conveyor, it was found that the unbalanced load is major factor to deteriorate the measurement accuracy of mass.

1. Introduction
Check-weigher is a device that performs mass measurement and selection continuously while conveying the object with a belt conveyor and is active in various fields such as food, medicine and industrial products. Although the load cell type scales are often used for mass measurement, the measurement accuracy deteriorates due to vibration of the conveyor, floor vibrations through movement of people or other machines, etc. Additionally, since the weighing conveyor has a certain width (x-axis) and depth (y-axis), the load position changes for each measurement. Therefore, finding the influence of these factors on the measurement accuracy is one of the important factors determining the performance of the check-weigher.

In this paper, the behavior of the load cell type balance is analyzed statically using FEM method and dynamically analyzed in the impulse response experiment, and the influence on the measured value and measurement time is studied. As previously stated, since vibrations occurring on the weighing conveyor have various causes, a dummy conveyor is manufactured to simplify the characteristics, and this is analyzed. The final goal of this research is to improve the accuracy and speed of the check-weigher by formulating the influence of unbalanced load and compensating for the vibration, and this paper is a basic research of it.
2. Experimental device
In this study, the experiments were performed by the check-weigher with a load cell type balance to investigate the influence of vibration described above. The specification of this device are as follows: measuring range 12 to 3000 g, scale 0.1 g, selection accuracy ± 0.2 g. (Fig. 1) In order to further simplify the vibration phenomenon by the weighing platform, a dummy conveyor shown in Fig. 2 was produced. The dummy conveyor reproduces the same mass, dimension and center of gravity position as the actual conveyor, and the dummy motor is divided into four so that it can be fixed to all sides so that it can measure two types with and without an unbalanced load. In addition, nine points of positioning were carried out in order to study the change in the response due to the load position of the conveyor.

3. Experimental method
First, a 3D model of the mass measuring part was prepared using analysis software DEFORM ™ to analyze the deflection of the x, y, z axis components depending on the load position of the conveyor, a load of 200 g was added to 9 points of the weighing platform, Deflection in x, y, z axis direction was calculated. (Fig. 3) The mesh of each part at this time was 1 mm for the load cell, 2 mm for the frame covering it, 5 mm for the weighing platform. Next, impulse load was given to nine points to investigate the vibration frequency at which the load cell is affected by the vibration of the conveyor, and it was analyzed by FFT. Measurement was made 5 seconds before and after vibration occurred, and FFT was performed using MATLAB. In addition, as a test condition, the dummy conveyor was fixed to the mass sorter, and the case where the unbalanced load of the motor was applied and the case where the equal load was applied were compared.

Fig. 1 Check-weigher  
Fig. 2 Dummy conveyor  
Fig. 3 FEM analysis with DEFORM
4. Experimental results and discussion

4.1. FEM analysis
Table 1 shows the analysis results of deflection by DEFORM™. The Z-axis direction is the load direction and becomes the deflection amount of the main component, the X-axis direction is left-right twist, and the Y-axis direction is twist of front and rear. When comparing the point 22 which is the position of the center of gravity as a reference point, the deflection of the z-axis component increases in the third row and decreases in the first row. Also, the x axis component outputted a constant value at all points. This is the characteristic of the double beam type load cell\(^{(3),(4)}\), and the right and left twists are less affected by the change due to the measurement position. However, for the y-axis component, the value in the second row is largely output in the 1st and 3rd rows.

|    | Deflection [µm] |
|----|----------------|
| matrix | 11 | 12 | 13 | 21 | 22 | 23 | 31 | 32 | 33 |
| x axis | 0.23 | 0.26 | 0.28 | 0.22 | 0.23 | 0.26 | 0.23 | 0.26 | 0.29 |
| y axis | 0.19 | 0.16 | 0.17 | 0.03 | 0.01 | 0.02 | 0.17 | 0.16 | 0.22 |
| z axis | 1.87 | 1.96 | 2.05 | 1.80 | 1.89 | 1.98 | 1.86 | 1.98 | 2.09 |

4.2. Impulse response experiment
Fig. 4 shows the vibration waveform of equal load impulse response and FFT, Fig. 5 shows the vibration waveform of impulse response of eccentric load and the result of FFT. Impulse load input was done manually using impulse hammer. Peaks can be confirmed only in the vicinity of about 40 Hz under equal loading, which is vertical vibration. We believe that simplification of vibration, which is the design principle of the dummy conveyor, without the eccentric load by the motor is largely satisfied. In the case of eccentric load, beat was confirmed in the vibration waveform. In FFT, in addition to 40 Hz vibration, noise was confirmed around 36 Hz and 56 Hz.

As a consideration, vibration of 36 Hz was the main cause of beat, and when comparing at 9 points, since it occurred at the same rate as 40 Hz vibration, vibration of x axis direction (right and left twists of the weighing table) I think. Also, vibration at 56 Hz is vibration in the y axis direction (twist in front and rear of the weighing table) due to large noise in the 1st and 3rd rows. This is considered valid as it shows the same result as DEFORM analysis.

5. Conclusion
In this paper, we presented the behavior of check-weigher using load cell type scale from both static and dynamic characteristics. As a result of the static analysis by the FEM method, the influence of deflection due to the x-axis direction is small, and the influence of the deflection by the y-axis direction is remarkable. The frequency analysis for impulse excitation shows that vibration component only in the vertical direction appears in the case of balanced load. In unbalanced load the vibration components other than the vertical direction are generated, but the excitation to the center of gravity position, the vibration is only in the vertical direction in this case. The cause of the vibration other than the vertical direction will be examined in the future. In full paper, we will discuss the effect of unbalanced load on measurement accuracy and time.
Fig. 4 Impulse response with equal load (Fixed to check weigher)

Fig. 5 Impulse response with unbalanced load (Fixed to check weigher)

6. References
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