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Examination of the Repeatability of a Balance for Production Lines

The structure of a microbalance used with an automatic machine
and the influence of installation environment disturbances

Presented by: Naoto Izumo, Yuji Fukami, Yutaka Dodate, and Yoshikuni Sato, R&D Division 5, A&D Company, Limited

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The structure of a micro balance used with an automatic machine and the influence of installation environment disturbances

Naoto Izumo, Yuji Fukami, Yutaka Dodate, Yoshikuni Sato　A&D Company, Limited
Higashi-Ikebukuro,Toshima-ku,Tokyo 170-0013 Japan

Abstract

Recently, highly precise weighing instruments are frequently installed in automated machine lines and these fields require quicker and higher resolution and more delicate weighing. We developed a new weighing instrument that has a quick response and excellent performance at the microgram level.

This document presents an investigation of the product configuration, repeatability, and response speed and an analysis of environmental disturbances that cause poor reliability.

Keyword

Micro-gram, repeatability, environmental disturbance

1. Introduction

In the weighing field, the resolution is represented by a value that is calculated by dividing the capacity by the minimum display and this resolution value is used to determine the price of the instrument. In other words, the most important element of a weighing instrument is its resolution, and its price is determined by the technology to achieve it.

Currently, nearly all precision balances with a resolution of several hundreds of thousands to one or better are electronic balances, and their measurement principle is called the electromagnetic equilibrium method.[1] The electromagnetic equilibrium system comprises a pan and an electromagnetic equilibrium section on either side of a beam that is supported by a fulcrum. The weight on the pan is received by the fulcrum, and then a counterbalance force is applied by an electromagnetic force called a Lorentz force via the fulcrum. Further detail is beyond the scope of this document but basically the displacement of the beam is monitored, and a closed loop controls the displacement of the beam so that it is in the same position both before and after the mass is placed on the pan. This is referred to as the null method and it can achieve a resolution of more than 10 million to 1.

A null-method electromagnetic equilibrium balance doesn't simply offer a way to achieve high resolution. It also provides tremendous control benefits that result in high-speed response and improved resistance to vibration. Other methods such as tuning fork, strain gauge, and capacity methods, which are all classified as the diplacement method and often compared with the null method, do not offer abovementioned properties of the null method. In the automated equipment field requiring high precision, all weighing sensors use the electromagnetic equilibrium method. Recently, there has been a remarkable demand for weighing instruments for production lines with embedded mass sensors with a sensitivity of 1 μg. This can be seen by the increasing demand in growing technical fields for weighing of minute amounts, such as material and resist ink for liquid crystal used in displays for mobile phones and other devices, material for plastic molding of electric components such as LED chips, coating amounts of solder paste, and production management of secondary batteries.

When minute amounts are weighed, the setup environment can disturb the weighing instruments, resulting in problems such as poor repeatability and weighing value drift. To investigate these problems, we prepared a weighing instrument for production lines with a minimum display of 1 μg, manufactured a mass loader jig to simulate use in automated lines, and then collected data over a long period while using this jig. We determined that it is possible to confirm the effects of environmental disturbances quantitatively from the measurement results. This document reports the results from actual measurement data.

2. The weighing sensor configuration and determination of repeatability and response when used with automated equipment

○ We developed the Super-hybrid-sensor (SHS) [2], an electromagnetic equilibrium mass sensor with high-speed response, in 2000. Using the SHS, we developed a new mass sensor with a sensitivity of 1 μg that was released as the AD-4212B-23 weighing instrument for production lines (Fig.1). This weighing instrument has a capacity of 21 g and a minimum display of 1 μg. [3]

○ A weighing jig for automatic loading and unloading of a weight was constructed (Fig. 2) and the long-term performance and response speed of the AD-4212B-23 was measured. The loading/unloading cycle for weighing was set to 60 seconds. The weight was determined 30 seconds after the weight was loaded.

○ For the evaluation of it as a 1 μg balance, 10 adjacent span values (weight value minus zero point) from many measured values were used to calculate repeatability (standard deviation σ n-1). The results were then graphed as the repeatability.

○ One consistent problem when a weighing instrument is used with an automated machine is the time it takes for the weight display to stabilize. To investigate this problem, the time until the μg display stabilized was also measured.

Left: AD-4212B-23 operation section
Right: AD-4212B-23 weighing section

Fig. 1. Exterior of the AD-4212B-23

Left: Weight loading/unloading jig
(Weighing section placed on base board)
Right: AD-4212B-23 operation section

Fig. 2. Weight loading/unloading jig

3. Measurement results

3-1. Repeatability measurement results

A balance (AD4212B-23) and weight loading/unloading jig were set up both outside and inside a weighing room as shown in Fig. 3 and the weight was measured over 4 days.

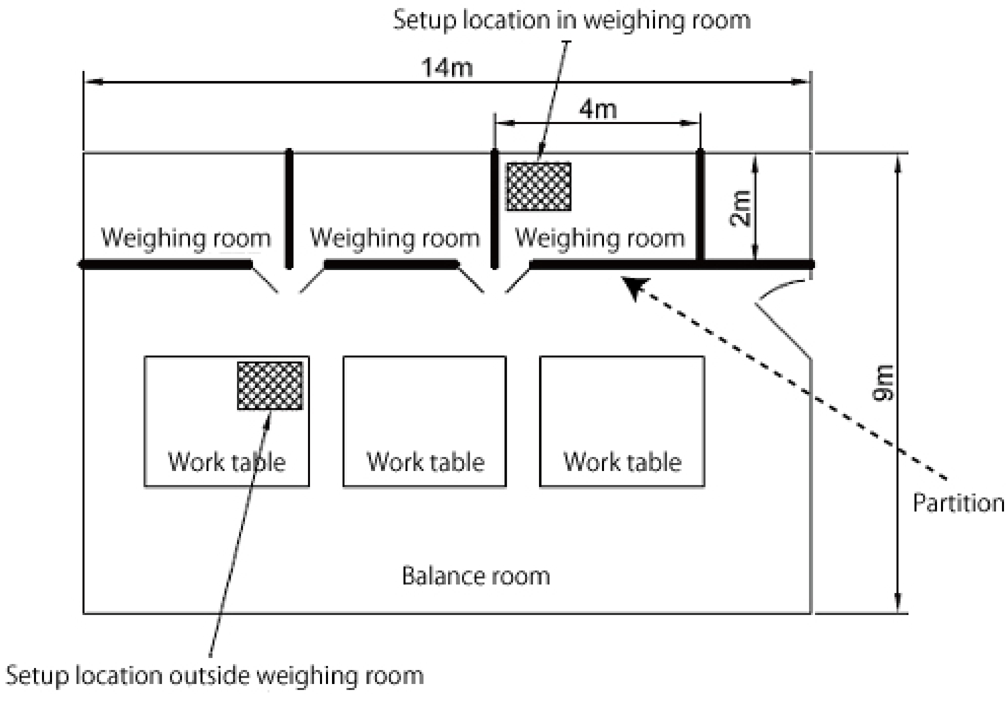

Fig. 3 Layout of balance room

Fig. 4 shows the data for weighing outside the weighing room.

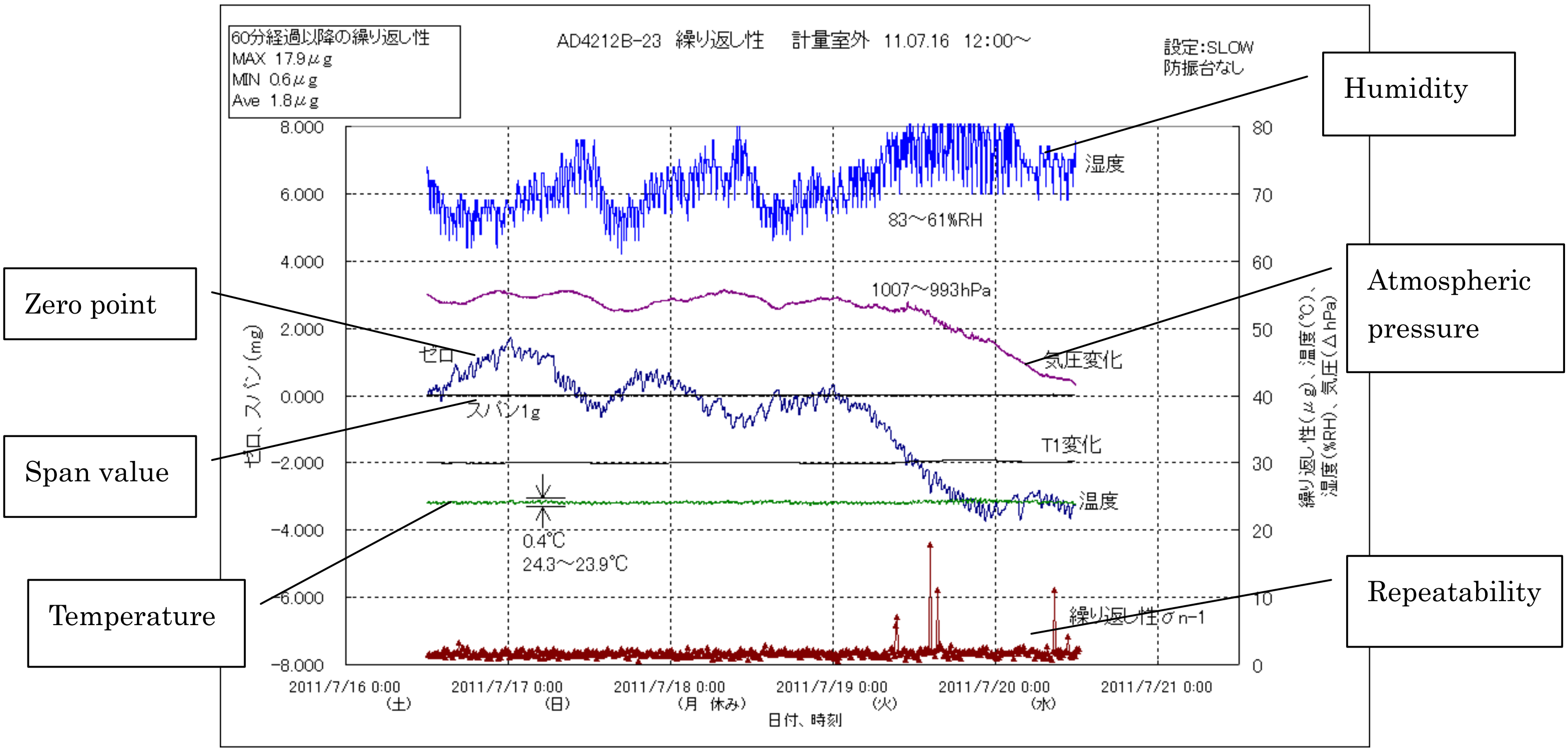

Fig. 4. Results for weighing outside the weighing room

The environmental changes over the 4 days were as follows: Temperature: 0.4 °C, humidity: 61% to 83%, atmospheric pressure: 993 to 1007 hPa. The instruments were outside the partitioned area, and people moved about around them. Ripples were found in the temperature data, with an accompanying ripple effect in the zero point data. Nevertheless, the span value (weight value minus zero point) when a weight of about 1.25 g was used was stable, and the span value repeatability was good at 1.8 μg.

Fig. 5 shows the weighing results when the same balance was set up inside the weighing room shown in Fig. 3.

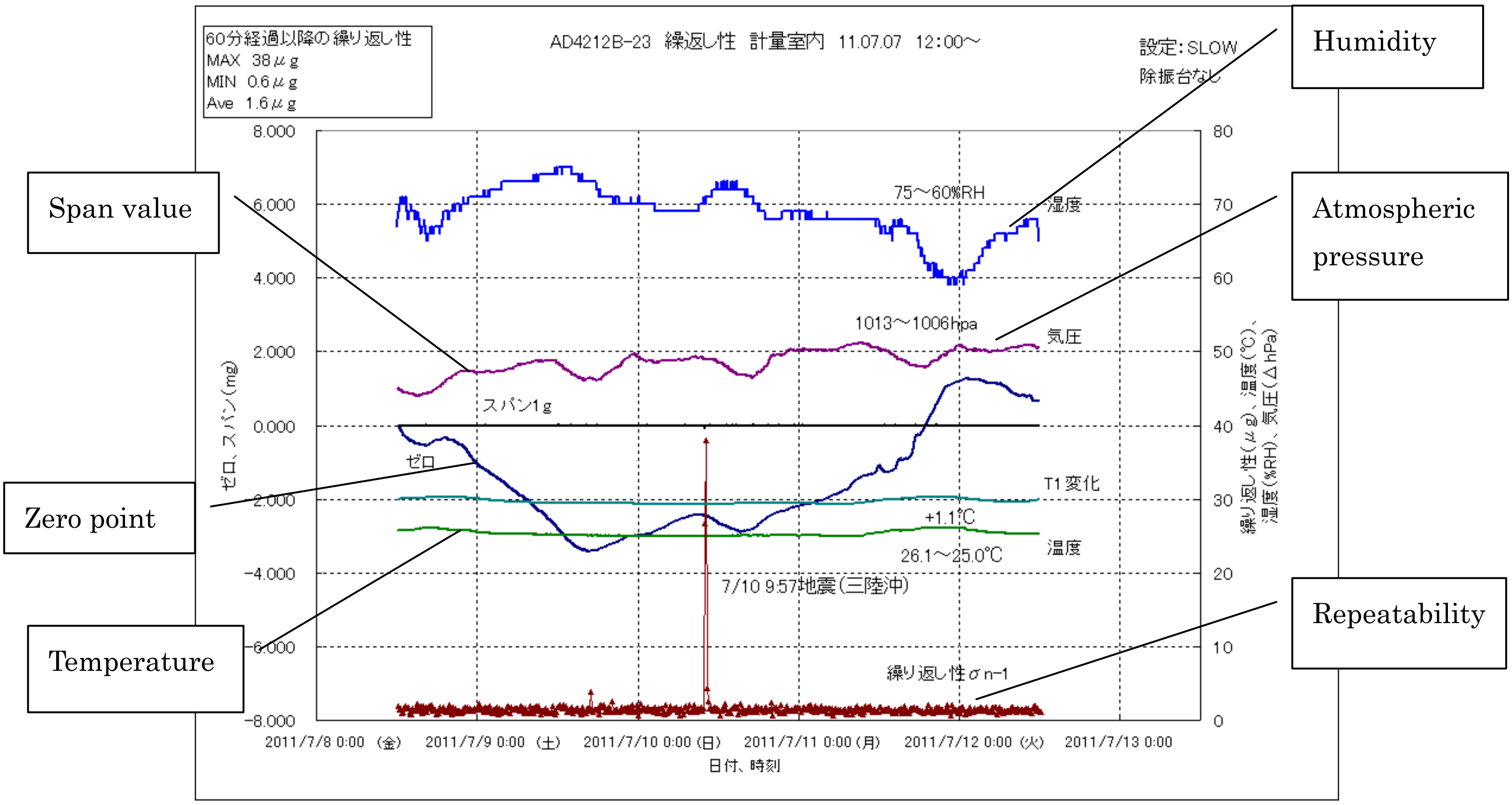

Fig. 5. Results for weighing inside the weighing room

The environmental changes over the 4 days were as follows: Temperature: 1.1 °C, humidity: 75% to 60%, atmospheric pressure: 1013 to 1006 hPa. Because the balance was set up inside the partitioned area, no ripples were found in the temperature data or the zero point data. The weighing data during this period had a zero point width of 5 mg, and the span value (weight value minus zero point) showed little change.

The zero point variation was large, likely due to humidity changes caused by changes in the weather. However, the repeatability calculated from the 10 adjacent span value measurements had an average of 1.6 μg, and when the zero point was deducted, the performance sufficiently satisfied the specifications for a micro-balance. The data showed that microgram measurement was not affected at the abovementioned level of environmental changes. It should be noted that the peak in the data at 10 AM on July 10th was caused by the balance detecting an earthquake that occurred off the Sanriku coast (9:57 AM on July 10th).

3-2. Response speed (balance in weighing room, automated machine used, no anti-vibration table)

Fig. 6 shows the response speed when a 1.25 g weight was loaded using an automated machine. The balance has an environmental setting function and its software can change the averaging of the weighing value display at three stages. In other words, when there are environmental disturbances such as breezes and minute vibrations, the balance can apply stronger averaging to make the display value as stable as possible. When this function is used, the response speed is slowed, so the time taken until the display is stable becomes longer. Fig. 6 shows that the stabilization times for the FAST, MID., and SLOW modes under the same conditions (display variation of Δ2 μg/s) were 11.3, 13.7, and 16.2 seconds, respectively.

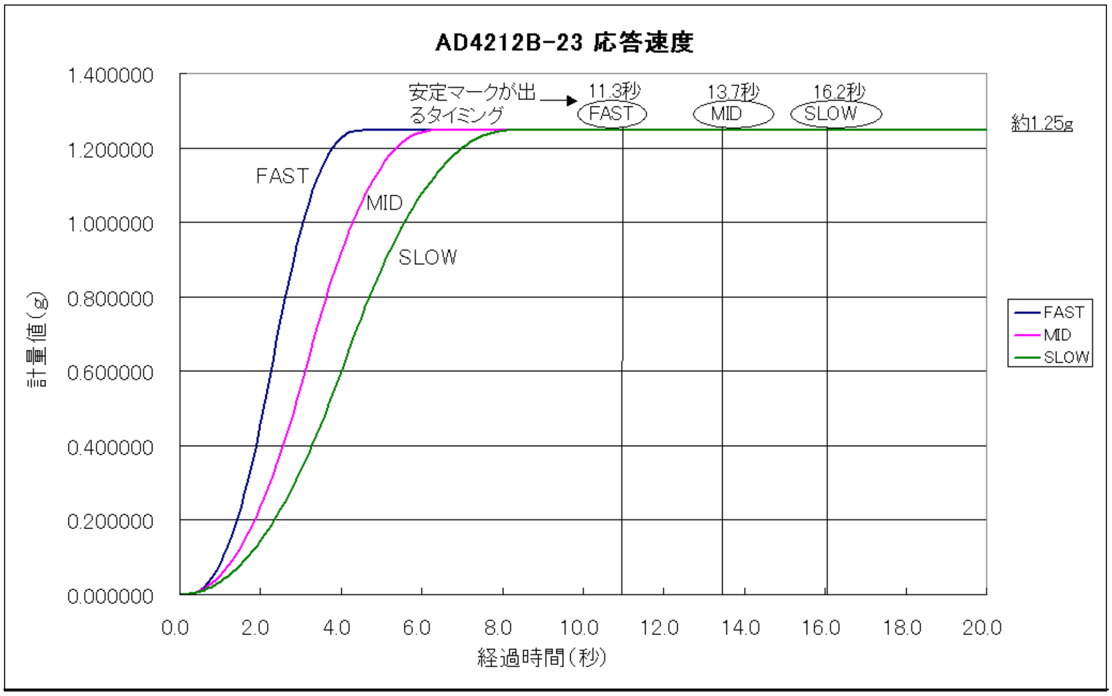

Fig. 6. Response speed

4. Discussion

○ The environmental causes affecting the repeatability of micro-balances for automated machines

The results of continuous weighing over a long period using an automated machine clearly showed the error factors affecting the performance of the micro-balance. One such factor, and the one that occurs constantly, is the zero point variation caused by temperature and humidity changes that accompany meteorological changes. It was also clear that the air conditioning used to control the temperature caused temperature ripples, which affected the zero point data. More specifically, the air conditioning switching on and off changed the temperature several degrees and this caused instability of the zero point data. One effective method to solve this problem is to use partitions or other dividers to separate the setup location of the balance from the space where the air conditioner is located.

○ Repeatability

The stability of the span value, which is acquired by subtracting the zero point from the weight value, was repeatable and stable at 2 μg or less, regardless of the instability of the zero point. From this fact, it was determined that acquiring zero before each measurement is essential for accurate measurement. When zero cannot be acquired for each measurement, it is necessary to acquire the zero point and weight data continuously, and then subtract the zero point from the weight to acquire the span value either in realtime or after data collection.

○ Response speed

Measurement under a particular environment (weighing in a balance room, automated machine used) was stable with a microgram-level weighing time of 20 seconds or less. It is often said that the display of a micro-balance does not stay stable for a long period when the balance is used with automated machines. However, analysis of the long term data acquired for this document shows that it is possible to reduce environmental disturbances and realize the true performance of the product.

5. Summary

The investigation described here explains the necessity of controlling temperture variations during microgram-level weighing. In particular, it was clear that zero point variation is very sensitive to temperature changes while span value variation is not. The repeatability guarenteed for the span value is ensured regardless of the variation of the zero point. It has long been said that a balance should be zeroed before obtaining the weight value (span value). Therefore, it is considered best to either acquire zero with each measurement or subtract the zero point from the weight value after weighing.

To prevent consistant instability of weighing values, which can be caused by air conditioner use (temperature ripples, wind force, and humidity changes), the movement of people (vibrations, pressure changes), and heat sources near the balance, it is important to acquire long-term data for analysis to understand the usage conditions of the weighing instrument. Possible causes of sudden instability of weighing values are far-off earthquakes and, although they did not appear in the data presented in this document, building tremors from passing low pressure. It was determined that this sudden instability cannot be countered proactively using current technology but instead disturbances should be reduced through passive measures, such as using a anti-vibration table.

The field of automated machines requires more than just repeatability of weighing values. It also demands a short stability time, even at the microgram level. It was determined that the key to solving response speed issues is the same as the solution for repeatability: reduce environmental disturbances to maintain the true performance of the weighing instrument.

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