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A VERSATILE WEIGHING SYSTEM FOR STANDARD WEIGHTS MEASUREMENT USING MANUAL PLATFORM BALANCES

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Abstract:

Platform-type manual mass comparators are commonly used for the calibration of high precision heavy mass standards. While some automated heavy mass calibration systems are available commercially, they are very expensive and are not economically viable for most laboratories offering calibration services.

NMC, A*STAR has developed a low-cost, automatable, weights handling system for use with commercially available platform type mass comparators. This system is designed to be versatile and adaptable for easy loading and unloading of reference and test mass during calibrations.

With this system, it is possible to achieve a marked improvement in repeatability measurement by as much as three times as compared with manual weighing using the same comparator. The system reduces the wear and tear of the mass standards and drastically reduces the risk of injury to calibration personnel due to lifting of heavy masses.

Keywords: mass comparator, calibration, heavy masses, low-cost, versatile, adaptable, automated, weights.

1. INTRODUCTION

Standard weights are high precision and accurate reference standards for the unit of mass. These weights are used for the calibration of balances for scientific, industrial, commercial, trade and legal purposes.

Standard weights are made of high quality stainless steel with highly polished mirror image surface finishing. They come in different mass range and are classified into different accuracy classes. The higher the accuracy class, the more stringent are the manufacturing, storage, usage and calibration requirements. International standards such as the OIML R111 [1] and ASTM E617 [2] have clear guidelines and instructions for the manufacturing, storage and calibration of these standards weights.

To meet these requirements, national metrology institutes and commercial laboratories have to perform measurements in climatically controlled environment, use prescribed methods with repeated measurements, and use of balances with suitable resolution and accuracy.

Calibration of high precision heavy weights or mass standards (greater than 20 kg) is a laborious and tedious process. Test weights, together with the reference weight, have to be placed alternately and repeatedly on a balance for measurement in a controlled environment.

Presently, commercially available high precision automated weighing systems have limited weighing ranges (maximum 60 kg). They cater to weights of a certain shape and size, and are extremely expensive (usually over S$500k) and are not economically viable for most developing or third world national metrology institutes, commercial calibration laboratories and private companies requiring weighing.

Manual platform-type balances used for heavy weights measurement have open top platform design suitable for handling weights of different shapes and sizes. They have a larger continuous weighing range and are very much cheaper than the fully automated systems. These balances, however, are of lower accuracy and precision, are exposed to greater environmental disturbances during measurement, giving rise to larger measurement errors and uncertainty and are thus not sufficient for high precision mass measurement.

There is an obvious gap in the precision measurement of weights between the automated and the manual platform-type balance. It is possible to improve the precision and accuracy as well as the overall performance of mass measurement using automated loading operation with platform-type manual balance, but at a fraction of the cost of the fully automated systems

NMC, A*STAR has designed and developed a low-cost, automatable, weights handling system for use with commercially available platform type mass comparators. This system is designed to be versatile and adaptable for use with different types of platform balances for easy loading and unloading of reference and test mass during calibrations. With this system, it is possible to achieve a significant improvement in the performance of the balance for higher precision measurement.

2. AIM & OBJECTIVE

The aim of the project is to build an automated weighing system to improve the calibration process for high precision standard weights. Advantages of the system are as follows:

(i). Capable of calibrating weights of different shapes and sizes over a wide weighing range (up to 60 kg).
(ii). Flexible and adaptable for use with platform balances with various weighing and pan sizes from different manufacturers.
(iii). Can be automated and be fully integrated with the balance for data acquisition during weighing process.
(iv). Significantly lower cost of construction and maintenance.
(v). Able to improve the performance of the balance and the weighing process to be of comparable precision and accuracy as the commercially available automated systems.

Technologically, the weighing system adopts the weighing principles and set-up commonly associated with small mass balances for heavy mass applications. Developing third world national metrology institutes and small and medium size local commercial calibration laboratories can be the main beneficiaries of this system.

3. FEATURES OF THE SYSTEM

There are several important features in the proposed automated weights measurement system. These includes the precision belt drive system; the slotted loading platform and fork shaped weighing pan; adjustable mounting platform support; open top draft shield and the dedicated integrated software for data collection and calculation of weighing results.

A. Overall Mechanical Design

The overall mechanical design of the system consists of three main parts; the draft shield, weighing platform & the precision belt drive system.

The draft shield design is based on an open top and open front concept with easy accessibility especially for the loading of heavy weights. When the draft shield is fully closed, it is able to minimise the external draft effects on the sensitive balance pan (see Figure 1).

The platform for the weights is adjustable and can be released and adjusted easily to adapt to different balances with different heights. The draft shield can be easily removed and attached for portability and easy adjustment of the platform height. The platform is designed with slots, stable and strong enough to withstand a combine mass of over 200 kg.

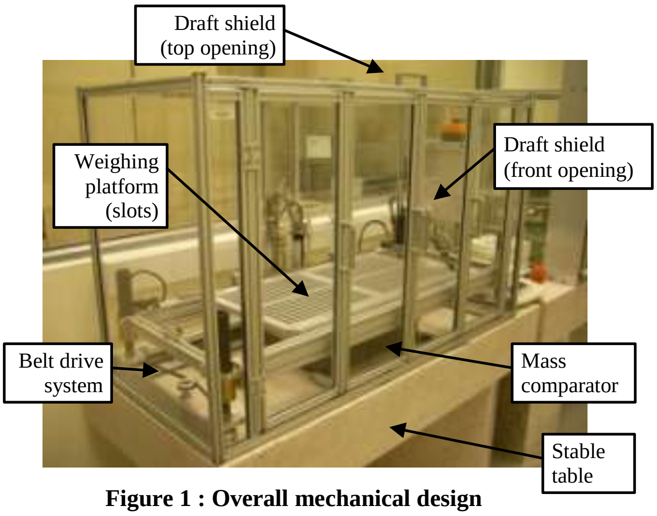

Figure 1 : Overall mechanical design

B. Precision Drive System

The precision belt drive system is designed to provide movement in the vertical and the horizontal direction. It consists of four lead screws (see Figure 2 & 3) and a series of belts driven by two motors.

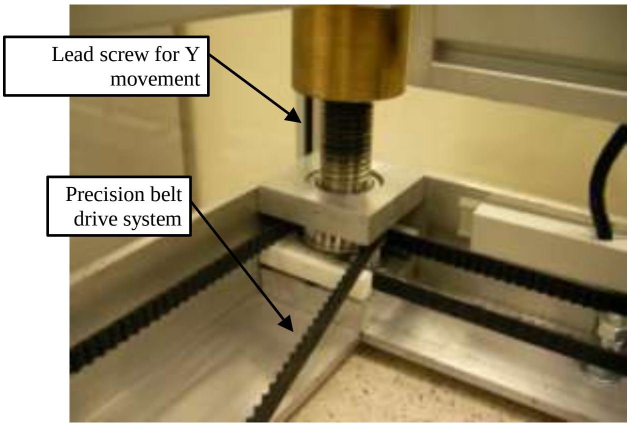

Figure 2 : Precision belt drive system

A schematic diagram of the belt drive system with the position of the four lead screws for the vertical movement is shown below (Figure 3).

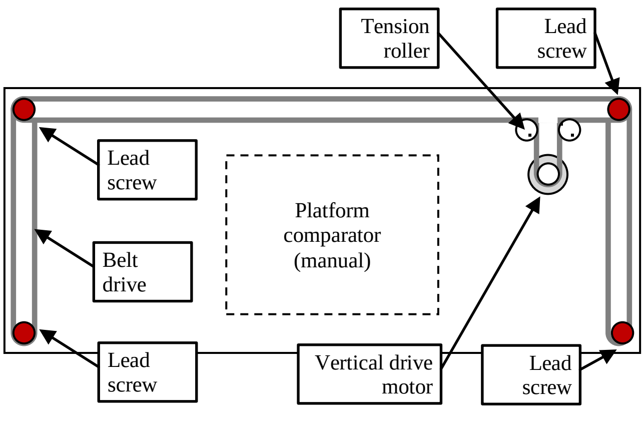

Figure 3 : Schematics of the precision belt drive system for vertical (Y) movement

Figure 4 below shows a schematic diagram of the belt drive system for the horizontal movement.

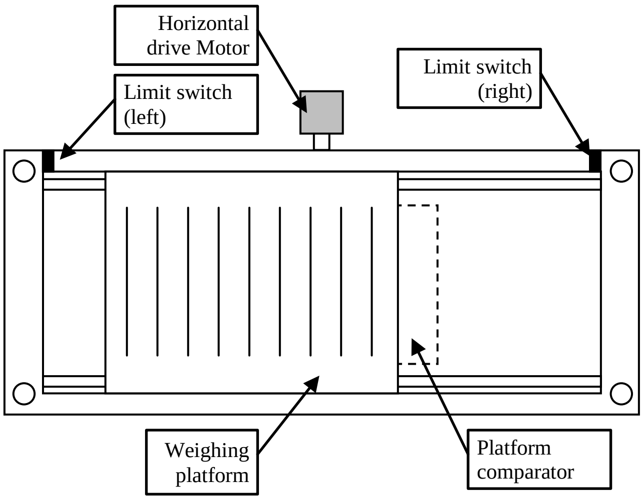

Figure 4 : Schematics of the precision belt drive system for vertical (Y) movement

The linear horizontal and vertical motion is programmable, allowing controlled acceleration and deceleration movements of the platform, resulting in time savings and consistent controlled loading force that gives more accurate weighing results. As the linear motion is accurate and repeatable and is able to load the weight on the weighting pan at the same place all the time. With this precision movement, it eliminates the need to center the weight or use any self-centering devices that may introduce addition movements on the weighing pan.

To prevent over travel, limit switches (see Figure 5 & 6) are located at strategic locations in the horizontal and vertical plane. Safety measures are built in to prevent simultaneous horizontal or vertical movement. A manual switch controller controls all the movement of the platform.

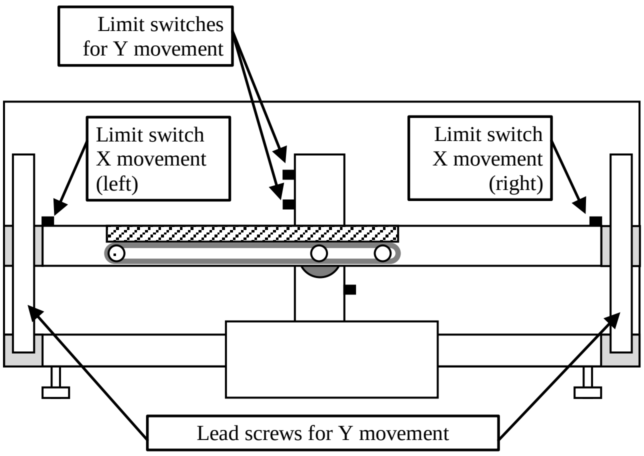

Figure 5 : Locations of the limit switches in the belt drive system for the vertical & horizontal movement

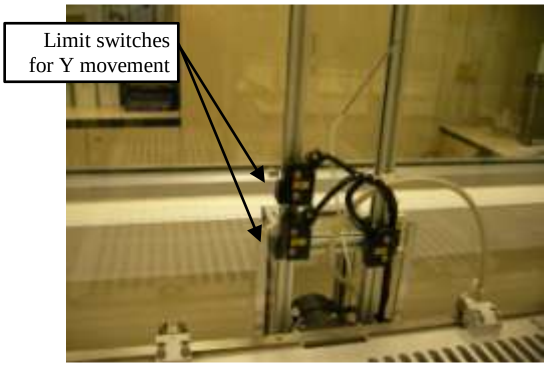

Figure 6 : Limit switches strategically positioned to prevent over-run of the weighing platform

The slotted loading platform (see Figure 7) and the fork shaped weighing pan are designed to work as a pair. A loading platform with weight is to be lowered into a fork-shaped weighing pan. The weight can be gently transferred over to the weighing pan smoothly with minimum impact and disturbance, thus requiring shorter settling and stabilisation time for data acquisition. This method is commonly used in commercial high precision balances but at a much smaller mass range, usually less than 1 kg.

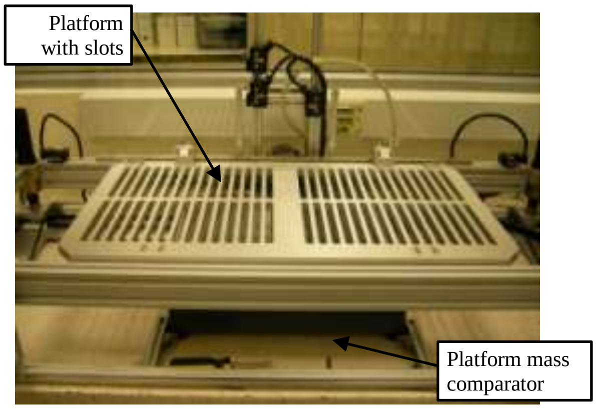

Figure 7 : Loading platform with slots

The adjustable mounting platform support is an important feature, designed in such a way to allow the use of different platform balances with different sizes. This allows users to make use of their existing balances instead of purchasing new one, thus results in costs and time savings.

The system comes with a control box (see Figure 8) that has various features; namely "On/Off switch and the variable speed controls for changing the speed of the horizontal and the vertical movements, An emergency switch is also built in to stop the system in the case of any unforeseen circumstances.

Figure 8 shows a picture of the layout of the control box with the various control functions.

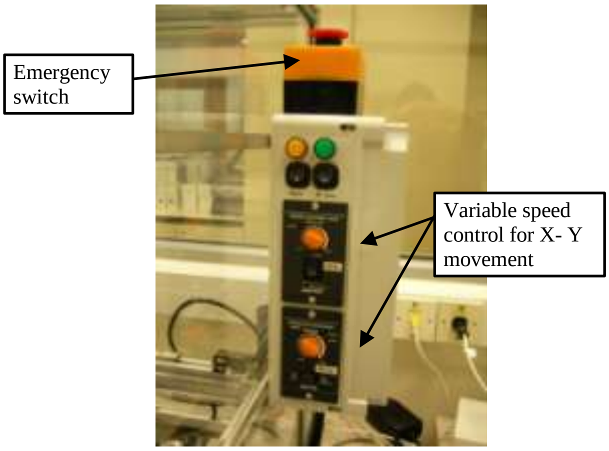

Figure 8 : Control box with emergency switch

C. Software & Integration

Two distinct software programmes are required for this system; one for controlling the movement of the linear belt drives, and another for the integration of the balance for automated data acquisition.

The software is in the process of being written. The dedicated integrated software for data collection and calculation of weighting results is designed to be versatile and robust to control the linear belt drive system, allowing precision control and efficient movements. The software will be fully integrated with the linear belt drive system and the balance digital input/output allowing automated movement and data acquisition.

4. RESULTS

The system was extensively tested to run-in the mechanical parts and over three different weight ranges of 5 kg, 25 kg and 50 kg.

For each weight range, at least four series of A-B-A weighing sequences were tested. The 25 kg range was repeatedly tested over a period of more than six months in the manual and assisted weighing mode to ensure that the measurements are repeatable and reproducible.

The results obtained were tabulated as the repeatability of the mass comparator for comparison. The standard deviation is obtained using the following formulae :

$$\sigma = \sqrt{\frac{\sum_{1}^{n}(r-\bar{r})^2}{n-1}}$$

where,

σ = standard deviation
r = result of weighing (A-B-A)
$\bar{r}$ = average weighing result
n = number of weighings

Preliminary results obtained are tabulated below:

Min Std Dev in mg (Best of 5 A-B-A)

Series	5 kg	25 kg	50 kg
1	1.14018	1.00063	1.14018
2	0.70711	1.22471	1.14018
3	0.89443	0.71117	1.14018
4	0.83666	0.89403	1.00000
Average	0.89459	0.95764	1.10513
Max Diff	0.43307	0.51354	0.14018

Table 1 : Repeatability performance of the system for different weight range obtained from 4 series of five A-B-A measurements

The results in Table 1 shows that under the assisted weighing mode, the average repeatability achieved across the 3 weight ranges are well within 0.2 mg of each other.

On averaging the repeatability performance over the four series of results, the 5 kg weight range has the smallest repeatability (0.89 mg) and the 50 kg weight range has the largest repeatability (1.10 mg).

On the maximum deviation of the repeatability performance over the four series of results, the 5 kg and the 25 kg weight range has a comparable repeatability deviation (0.43 mg and 0.51 mg respectively). The 50 kg weight range however, shows the best repeatability performance to well within 0.14 mg. This seems to show that the system is more stable at the higher weight range

The manufacturer quoted repeatability specification for the manual comparator is 7 mg. With the above results, it suggests that the system is able to improve the weighing performance by up to six times at the 50 kg weight range but up to seven times better at the 5 kg weight range.

Min Std Dev in mg (at 25 kg)

Series	Manual	Assisted
1	3.08446	1.00063
2	3.78740	1.22471
3	0.89506	0.71117
4	-	0.89403
Average	2.58897	0.95764
Max Diff	2.89234	0.51354

Table 2 : Comparison of result between manual and system assisted weighing for 25 kg weight range

Table 2 shows the comparison between manual weighing and assisted weighing at the 25 kg range. On the average, the repeatability performance with the assisted weighing is improved by about 3 times over the manual weighing.

Assisted weighing is also more stable and reproducible as it has a much smaller difference in the repeatability over the four series (0.51 mg) as compared with the manual weighing (2.89 mg).

4. CONCLUSION

The automatable weights handling system developed by NMC, A*STAR is a versatile system that can be used with different commercially available platform type mass comparators. With the use of this system, the performance of the manual comparator can be improved by as much as seven times as the specification stated by the manufacturer. The weighing performance, assisted by the system is improved by about three times when compared with manual weighing. The assisted weighing system is a viable alternative to more established commercial weighing systems, but at only a fraction of the cost.

5. REFERENCES

[1] OIML R111-1 Edition 2004 (E), International Recommendation, Weights of Class E1, E2, F1, F2, M1-2, M2, and M3; Part 1: Metrological and Technical Requirements, International Organization of Legal Metrology, 2004.

[2] ASTM E617-97(2008) Standard Specification for Laboratory Weights and Precision Mass Standards, ASTM International.