Drive system alignment calibration of a microgravity drop tower of novel design

2013 J. Phys.: Conf. Ser. 450 012049

(http://iopscience.iop.org/1742-6596/450/1/012049)

Drive system alignment calibration of a microgravity drop tower of novel design

J Trunins[1], **B P Osborne**[2] **and A Augousti**[1]
[1] Kingston University, Penrhyn Road, Kingston, KT1 2EE, UK
[2] The University of New South Wales, High St Kensington, NSW 2052

Abstract. We report here the calibration of the drive system of a new scientific facility for production of microgravity, operating on a novel design of electromagnetically driven platform. The construction achieves the design specification of alignment of the guide rails to better than 0.254mm across the entire guide rail height of 8m, despite a small lean to the right (within tolerance) and it was noted that this alignment is improved by the presence of the trolley that carries the platform.

1. Facility design

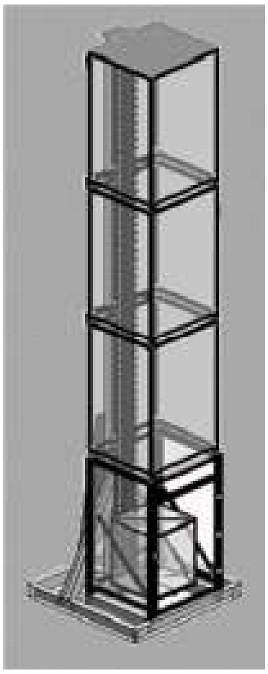
A microgravity drop tower has been developed at Kingston University London (KUL) [1], based on novel electromagnetic linear actuation. Microgravity research is important in a range of applications, including fundamental studies on the behaviour of liquids injected through nozzles for understanding fuel flow and transfer in orbit [2], as well as broader applications such as growth of crystals [2] for pharmaceutical and other industrial applications.

1.1 Outline of drop tower design

The KUL drop tower facility is 8m in height (figure 1), and is scheduled for final commission at the end of July 2013. According to its design, programmable velocity profiles will be available, and up to 2.2s of microgravity will be achievable. The payload is situated inside housing with a drag shield, to which the actuating motors are attached, and the whole is housed within a safety surrounding. The remainder of this paper is concerned with the calibration of the alignment of the drive system of this novel facility.

1.2 Drop tower drive subsystem design

The drive system consists of several primary components, namely the base support beam, the motor installed on the trolley and the magnetic track, the guide rails and the position fixing L-brackets (figure 2). The base support beam is an 8.4 m long I-beam. This beam is manufactured by contractors with pre-cut holes for magnetic tracks and the installation of fixing brackets. The magnetic tracks are fixed on the I-beam in line with no spacing in between. The physical attachment of the trolley itself helps to keeps the motors aligned. It also has the guide rail rollers installed with the right spacing from the motors. The position of the motors has been designed so that the offset from the centre line of the magnetic track is kept within 0.254 mm. This guideline is set by the providers of the motor and magnetic track. The guide rails, which are installed along both sides of the magnetic track on the I-beam, are used to keep the position of the motor relative to the magnetic track within the required limits.



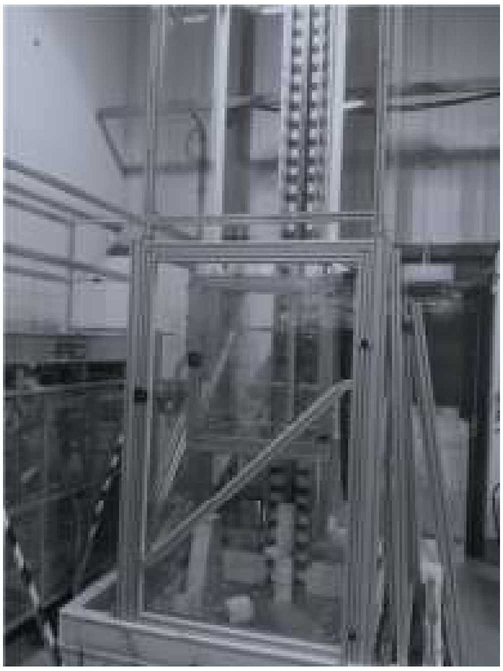


Figure 1. Drop Tower. Left – drop tower CAD model. Right – drop tower assembly

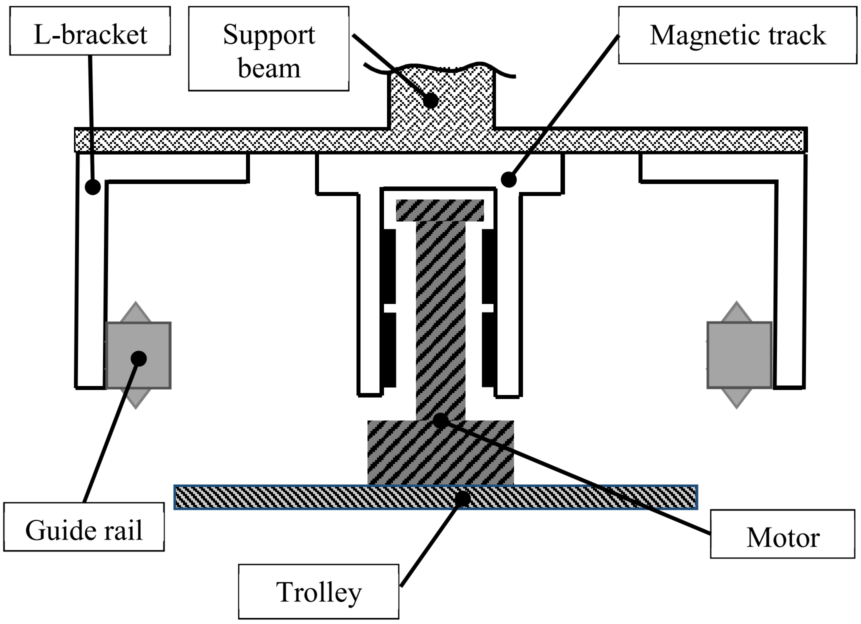


Figure 2. Drive system design. Arrows show the main components of the system

2. Drive subsystem assembly

The first step of the assembly procedure was to install the magnetic track. The magnetic track was attached to the I-beam with untightened bolts. The long line gauge and brackets were used to align the track of the magnets and after that the bolts were tightened. The bottom magnetic tracks were not installed in order to allow the motors to be slid in later after the evaluation of the system had been completed.

The next step was to attach the L-brackets, followed by installation of the guide rails. Using a pre-manufactured block gauge and the digital vernier callipers the rails were fixed at the right position.
After this milestone was achieved the motors could be installed on the trolley. But prior to this installation the alignment check of the guide rails was carried out using a laser distance gauge, as described in the following section.

3. Alignment check

The digital alignment check was done using the Baumer laser digital sensor (OADM 20i4460/S14C) [3] and National Instruments NI USB-6210 digital acquisition platform (DAq) [4]. The DAq has a USB interface which simplified the initial setup. Signal processing was performed using National Instruments LabVIEW SignalExpress software. Microsoft Excel was used for the signal analyses at a later stage.
The sensor was powered by a voltage supply of 10.00 ± 0.02V. The sensor range was 30 to 130 mm [3] but for our measurements a distance of around 80 mm was selected. The resolution of the sensor is 0.05 to 0.07 mm, which is well below our requirements of0.01 inch $= 0.254$ mm. The linearity error is ± 0.2 mm, again within the design requirements. The signal was acquired continuously at a frequency of 50Hz.

3.1 Sensor installation

The size of the sensor and the allowable minimum measurement distance did not permit the sensor beam to be positioned normal to the magnetic track surface. For that reason the sensor was positioned at a precise angle of 45^o to the surface. A range of tests were carried out and different sensor installations were explored. The first of these involved attaching the sensor to a single guide rail, while another was used to attach the sensor with the trolley installed.
Due to the high level of electromagnetic noise the DAq was enclosed inside a steel casing. This confirmed that the noise level was visibly reduced.

3.2 Alignment check procedures

Several procedures were employed to confirm the alignment. The initial step was to check the random electronic noise within the system. For this several static measurements at a constant position were taken. The confirmed the noise level was 0.1098 mm.
Following this static measurements were taken at several places on both sides of the magnetic track. Table 1 shows the results obtained.

Table 1. Static position measurements along the I-beam

Reading place (m)	Average reading (mm), Left ±0.11	Average reading (mm), Right ±0.11
1	80.51	80.54
3	80.52	80.53
5	80.53	80.52
7	80.54	80.51
8	80.55	80.50

The reading location was measured with respect to the ground. The average reading is the average value of a set of continuous measurements taken over duration of 2-5 s. These measurements were taken with a simple attachment to the guide rail.
The final test included the dynamic measurements, performed when the trolley was moved with a velocity that was approximately constant. These latter measurements were usually performed over a maximum period of 10 s at an average velocity of 0.8 ms^{-1}.

4. Results

Table 1 summarises the static point readings taken at different positions along the tower. The evident outcome is that the alignment does shift to the right. The measurements were assessed also for the introduction of measurement uncertainties which might arise following movement of the sensor while taking the measurements. Table 2 gives the values of this uncertainty, and confirms that the measurement uncertainty does exist but is well below the noise level of the sensor.

Table 2. Uncertainties for static readings

Read place (m)	Total distance (mm ±0.11)	Difference $(\mathrm{mm} \times 10^3 \pm 0.11)$
1	113.051	0.89
3	113.052	0.05
5	113.054	- 1.61
7	113.049	2.81
8	113.054	- 2.14
Average of distance:	113.052	

To confirm these measurements and also to include the alignment along the whole length of the rails the dynamic measurements were undertaken. Figure 3 shows a graph of initial data readings from a typical run. Here it is possible to see the spikes which arise from gaps between the magnetic tracks. This is due to the fact that the signal beam passing over the gap gets trapped, which results in a non-reading value returned. In this data, at our selected frequency of data acquisition, this corresponds to corruption of a set of 5-10 readings.

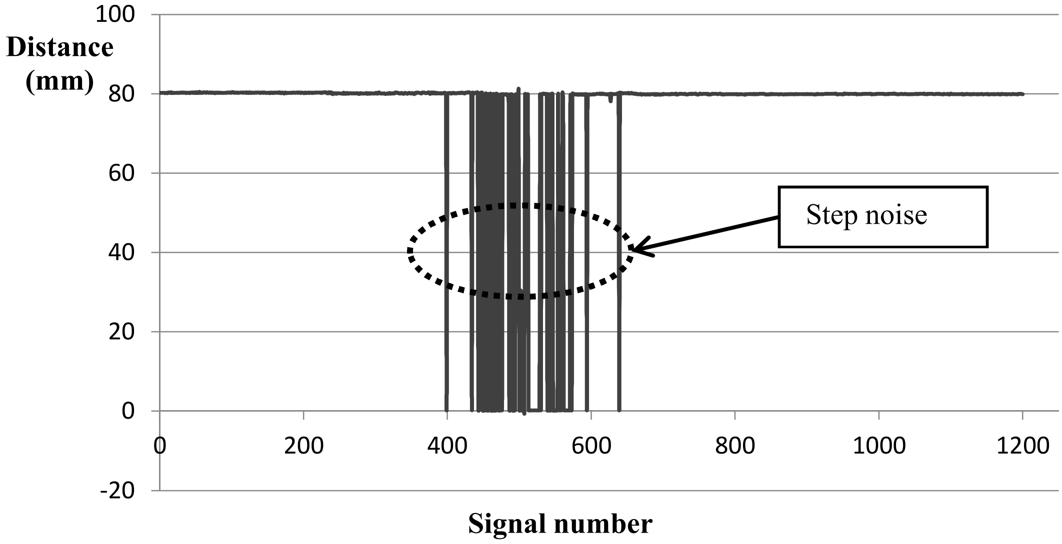


Figure 3. Initial signal readings. The arrow shows the location of corrupted data

These values were identified in the data set and were substituted with previously received non-corrupted readings. Additional smoothing was achieved by performing a boxcar average over 7 values as shown in figure 4. It is important to note here that the quantity of the selected readings is set so as not to affect the overall measurement quality. From the design perspective the L-brackets were positioned with a centre to centre spacing of 125 mm. As the beam does not buckle it was only important to make sure that at least two reading were taken to characterise this spacing, which results in needing to take measurements at least every 62.5 mm. With our measurement rate (50 Hz) and velocity (0.8 ms^{-1}) this corresponds to 7.8 measurements.

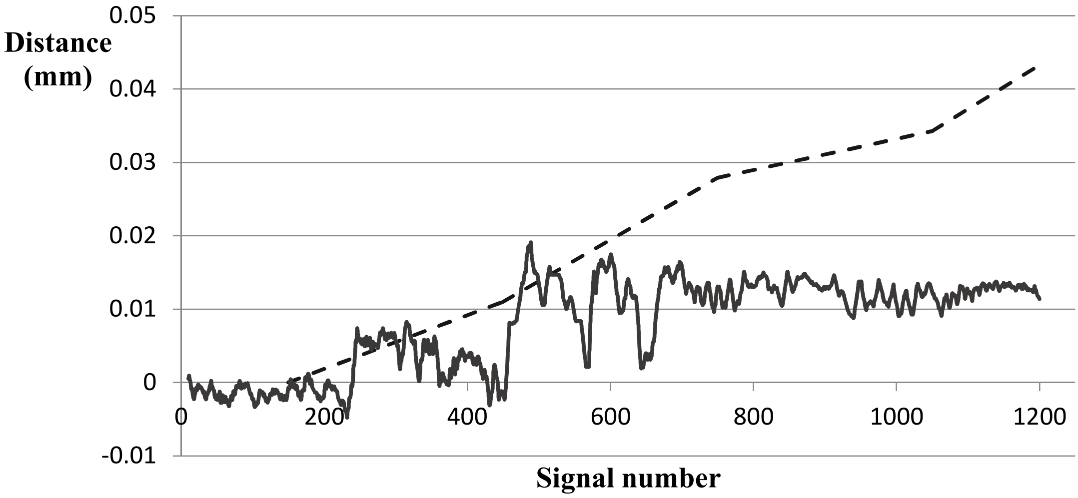


Figure 3. Processed signal readings. Solid line – dynamic test, Dashed line static test

The graph shows the values with respect to the base value which was used from static readings. The dashed line represents the static readings that were taken before. The difference here is explained by the presence of the trolley which is connected to both guide rails and provides additional alignment stability when the system is disturbed. Nonetheless the presence of an offset to one side has been confirmed, but within the tolerance limits of the design as both tests have verified.

5. Conclusion of the work

The installation of 8 meters of magnetic tracks and two linear motors were installed with a precision of 0.01inch (0.254 mm). Prior to that the guide rails were installed as motors guides to allow for this linearity to be achieved. A laser distance sensor with a DAq was used to check this alignment and confirm any required corrections. Several types of tests were used to determine the alignment achieved: the first was a static single point reading, and the second was a dynamic sliding test with the trolley installed. The results show that the alignments of the rails are within the tolerance requirements, despite a slight measured offset of the track. The maximum offset from the permissible tolerance was determined to be 17% and 5% respectively for the left and right rails respectively. It was noted that the presence of the trolley provides additional alignment due to self-correction achieved via averaging the misalignment of both sides of the guide rails. When this confirmation was achieved the motors were successfully installed and now await the first test run.

References

[1] Osborne B and Welch C 2012 Short duration reduced gravity drop tower design and development *Journal of the British Interplanetary Society* **65** 71-76
[2] Anderson S 1992 *Microgravity Honours Thesis* Mechanical Engineering The University of Queensland
[3] Baumer [Internet] OADM 20I4460/S14C [updated 2013 Apr 9; cited 2013 May 13] Available from: *www.baumer.com*
[4] National Instruments [Internet] NI USB-6210 [updated 2012; cited 2013 May 13] Available from: *www.uk.ni.com*