Tests with single two-wire pendulum

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Version 01 – removed factor two error in optical lever results

1. APPARATUS

We set up a single, two-wire pendulum using the test mass of the RAL marionette. The mass is 40.220kg. The wires were 0.71mm diameter. The clamp design was the same as that used in the noise prototype (jaws are stainless steel, vee-flat). The screws were tightened until the heads cammed. The “d” distance was about 1mm.

An optical lever was set up via a mirror at 4.1m, to a screen at a further 3.7m – total lever 7.8m.

The plan was to see whether we could see a permanent “set” caused by an enforced pitch, whether the effect was proportional, and whether an increase in “d” distance would decrease the permanent “set” for a given input displacement.

We measured the period of the pendulum at 10 cycles in 43 secs, 4.3sec per cycle.

2. TEST 1

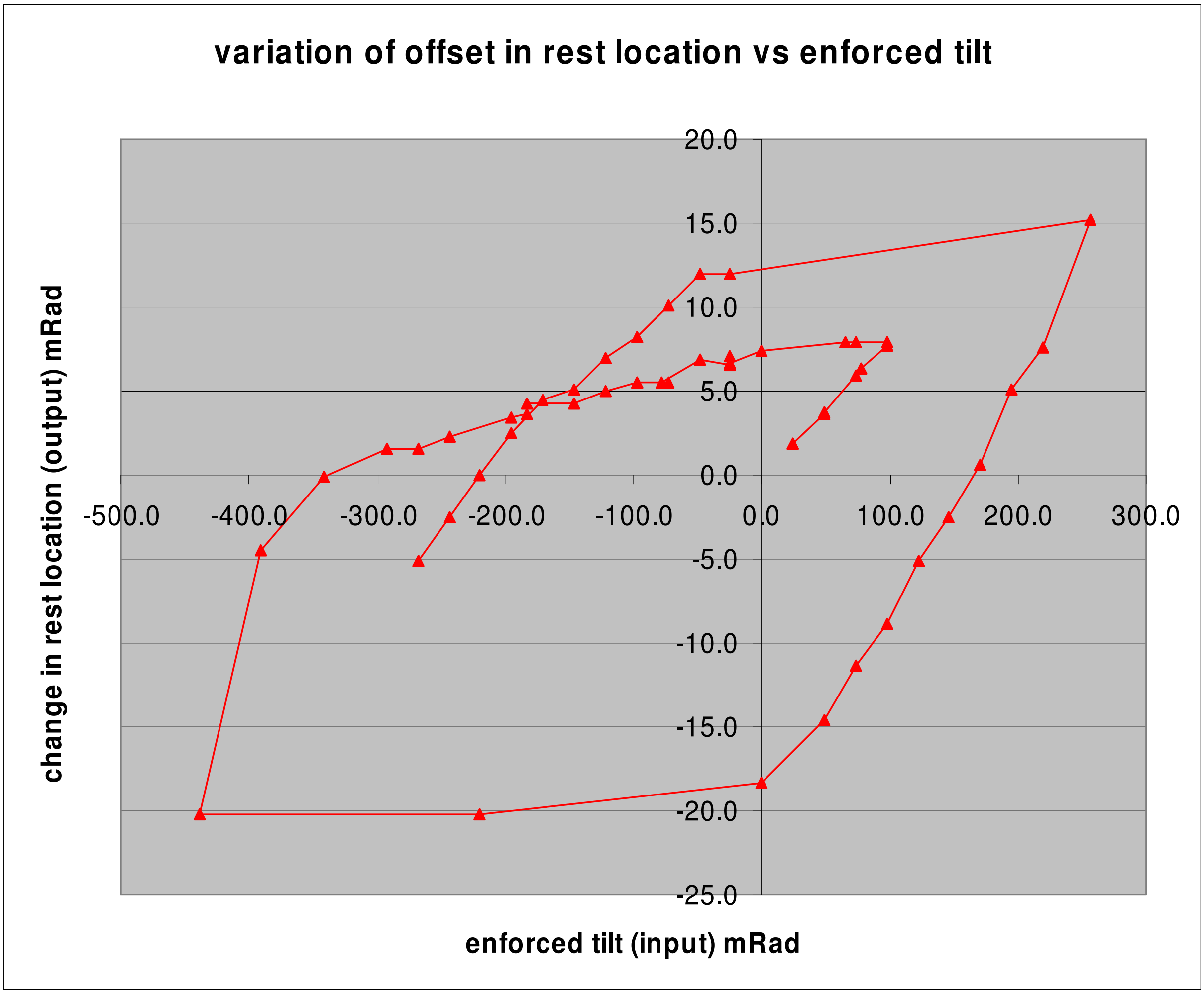
On the assumption that the pendulum might have a “range” of movement in the permanent set, we started by tilting the mass CW so that the top and bottom edges moved about 15mm. Call the start position 0. This produced a permanent movement of the spot at the 4.1m mirror of ~100mm (25 mRad).Call this -100. We then tilted the mass back CCW - the spot moved by about 200mm in the other direction. Reading is now +100. Reasoning that our start point could therefore not be at the end of any range, we tilted CW again aiming for roughly where we started (in fact we ended up nearer to the “-100” location, and reset the optical lever to suit). We then started to systematically apply tilts to the test mass (input tilt), allow it to return to the rest position, and observe whether the rest position had moved (output tilt). At first, we measured the input tilt on a piece of paper that could be placed over the mirror at 4.1m, and measured the output tilts on the screen at 7.8m using the same recording techniques as reported in T080030.

Input pitch +ve = CCW mov't of mass and lifting of spot (mm at 4.1m)	Input pitch mRad	Result number	TM residual pitch (mm at 7.8m)	TM residual pitch (mRad)	Measurement method[1]
start		1	0		A (input at 4.1m, output at 7.8m)
100	12.2	2	30	1.9	
100	12.2	3	30	1.9	
200	24.4	4	57	3.6	
200	24.4	5	60	3.8	
300	36.6	6	93	5.9	
320	39.0	7	100	6.3	
400	48.8	8	122	7.7	
400	48.8	9	125	7.9	
300	36.6	10	125	7.9	
270	32.9	11	125	7.9	
0	0.0	12	117	7.4	
-100	-12.2	13	106	6.7	
-100	-12.2	14	112	7.1	
-100	-12.2	15	104	6.6	
-200	-24.4	16	108	6.8	
-320	-39.0	17	88	5.6	
-300	-36.6	18	87	5.5	
-400	-48.8	19	87	5.5	
-400	-48.8	20	88	5.6	
-500	-61.0	21	79	5.0	
-600	-73.2	22	68	4.3	
-750	-91.5	23	68	4.3	
-750	-91.5	24	57	3.6	B (input at 2ms claed here to 4m, output at 7.8m)
-800	-97.6	25	55	3.5	
-1000	-122.0	26	37	2.3	
-1100	-134.1	27	25	1.6	
-1200	-146.3	28	25	1.6	
-1400	-170.7	29	-2	-0.1	
-1600	-195.1	30	-71	-4.5	
-1800	-219.5	31	-320	-20.3	C (input at 2msclaed here to 4m, output at 4.1, result judged by eye, scaled here to
-900	-109.8	32	-320	-20.3	
0	0.0	33	-290	-18.4	
200	24.4	34	-230	-14.6	
300	36.6	35	-180	-11.4	

[1] We varied the locations of the input (forced tilt) and output (observed residual tilt at rest) as the test progressed – see column "Measurement method". In all cases we factored the observed measurement (roughly) so that the recorded motion is that which would have occurred at the 4.1m mirror (for input motion) or at the 7.8m mirror (for output motion)

400	48.8	36	-140	-8.9	~8m)
500	61.0	37	-80	-5.1	
600	73.2	38	-40	-2.5	
700	85.4	39	10	0.6	
800	97.6		80	5.1	D (input and output at 2m, scaled here to 4m and 8m)
900	109.8		120	7.6	
1050	128.0		240	15.2	
-100	-12.2		190	12.0	
-200	-24.4		190	12.0	
-300	-36.6		160	10.1	
-400	-48.8		130	8.2	
-500	-61.0		110	7.0	
-600	-73.2		80	5.1	
-700	-85.4		70	4.4	
-800	-97.6		40	2.5	
-900	-109.8		0	0.0	
-1000	-122.0		-40	-2.5	
-1100	-134.1		-80	-5.1	

The results are shown on this graph:



The behaviour is clearly hysteretic. We did not control of the size of the loop (we changed loading direction when we ran out space on the particular scale we were using to measure input or output, and we didn't see the full graph until we had finished!)

3. TEST 2

We had now gathered some information about hysteresis but were no closer to being able to predict what the effect of a particular tilt would be, starting from an arbitrary start point. Therefore, we could not explore the effect of changing the "d" distance[2]. We decided to try a different approach, which was to move the pendulum back and forth between two large limits, and see what the range of the resulting displacements was. This seemed to give a repeatable and predictable effect, so we then tried adding mass to the bottom of the test mass in order to raise the "d" distance, and see if the magnitude of the effect would vary.

To speed up result taking, we used a single screen for the optical lever at 2m from the test mass, and judged the position of the spot by eye against a scale in 5cm increments (for the large, input effects) and a scale in 1cm increments (for the smaller output effects).

3.1 Check that we can vary d in a controlled fashion

First we tested the effect of adding mass near the bottom of the test mass, by looking for changes in the pitch frequency. Added 800g mass at 110mm below centre. Should have changed d from ~1mm to ~3mm. Timed 10 swings at 35sec, or 3.5 sec per cycle. Added another 800g, d should now be about 5mm, period now 2.7sec. Removed both lots and timed it at 5.0sec. Why the pendulum period has changed from the initial measurement of 4.3 sec, we do not know. Hard to draw conclusions except that we are having a measurable effect on the d distance (period should vary with sqrt (d) so in ~halving the period we have ~quadrupled the d).

3.2 Replace all the 1600g weight.

Input movement, mm at 2m	Observed spot settling location, mm at 2m	Input mRad	Output mRad
Start	0		
+500	25	125	6.25
-500	5	-125	1.25
+500	25	125	6.25
-500	8	-125	2
+500	25	125	6.25
-500	8	-125	2

Range about 17mm (4.3 mRad)

3.3 Removed the 1600g

Input movement, mm at 2m	Observed spot settling location, mm at 2m	Input mRad	Output mRad
Start	32		8
+500	65	125	18

[2] If you can't predict what the motion be would be with no change, you can't tell if the change has had an effect.

-500	7	-125	2
+600	70	150	18
-500	8	-125	2
+500	63	125	16

Range about 55mm or 14 mRad

3.4 Added back 800g

Input movement, mm at 2m	Observed spot settling location, mm at 2m	Input mRad	Output mRad
Start	35		16
+500	40	125	10
-500	17	-125	4
+520	38	130	9
-500	17	-125	4

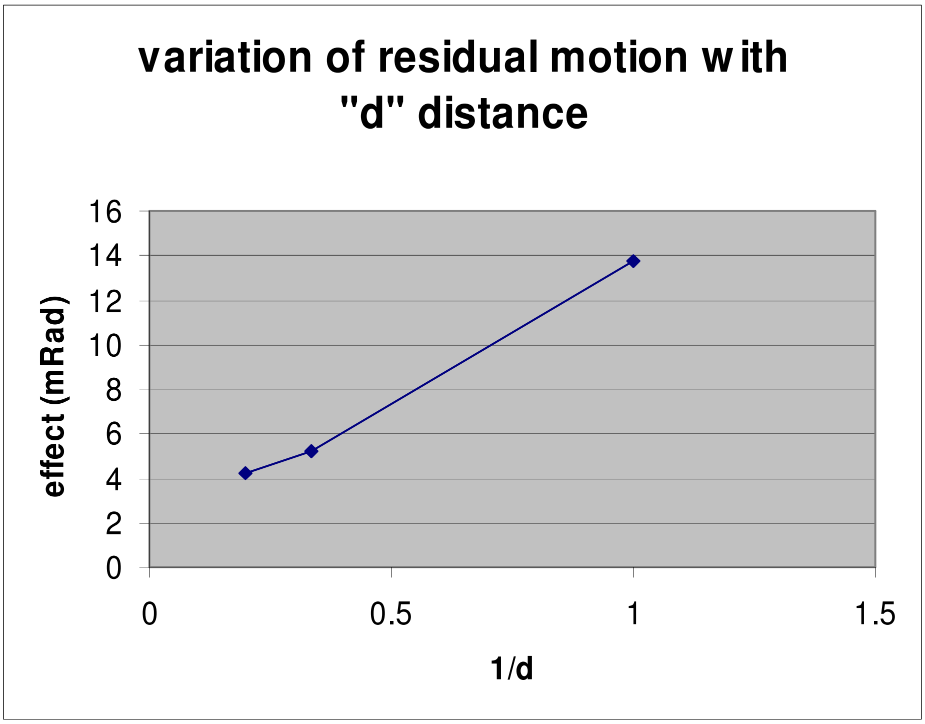
Range is about 21mm or 5.3 mRad

3.5 Overall result:

The range of output motion seen with a given input motion varies as follows:

	"d" distance (mm)	Range of output in mRad corresponding to input of +/- 125 mRad
Test mass on its own,	d = d0 (thought to be about 1mm)	14
With extra 800 g	d = d0 + 2 (thus about 3mm)	5.3
With extra 1600g	d = d0 + 4 (thus about 5mm)	4.3

There does seem to be a correlation of size of the effect with d distance. (I think you would expect it to go with 1/d.)



4. CONCLUSIONS

There is a clear hysteretic effect when a single pendulum is suspended from 2 wires using clamps of the design used in the noise prototype. The size of the mass and the wires, and the design of the clamp, were chosen to simulate those in the noise prototype, so from what we have seen here we would expect an effect of this nature to be present in the noise prototype. This is likely to explain at least some of the recent LASTI observations. (It does NOT explain for example why Brett sees a change in effect when he replaces the blade clamp bolts).

The residual motion at rest varies with “d” distance in a manner compatible with the theory that a given applied tilt results in a corresponding residual torque at the wire clamp breakoff points.

5. NEXT STEPS

As at the time of writing, we want to explore whether effects like those seen at “test 2” are also visible at lower sizes of applied displacement, and identify a lower limit if there is one. The alignment problems at LASTI suggest that if there is a lower limit it will be small. To that end we have installed a water bath around the lower edge of the mass (for damping) and a 10m optical lever. With this lever, the laser spot size is ~8mm, and the damping is such that it would seem feasible to detect changes in rest position of the order 5mm which, at that range, is 500microRad.

Having done that we will try to braze the wires into the clamps, then adjust the d distance to give about the same period, and see if the effect has been modified.