

Application of hysteresis model to quad SUS

Justin Greenhalgh, Ian Wilmut

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1. MOTIVATION

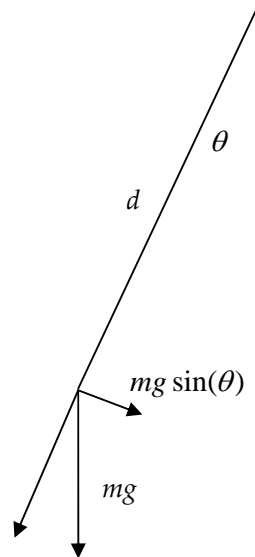
We wish to explore the idea that the anomalous tilt seen in the suspensions is a function of hysteresis in the wire at the point where it bends near the wire clamp.

A prediction of this model is as follows. We have measured the magnitude of the residual tilts on the two-wire pendulum (T080033, T080044). Knowing the “d” distance and mass of that pendulum we can calculate the associated torque that must be present to give the residual tilt. We can then express the effect for the wires we used in the two-wire test in terms of residual torque per unit input tilt. For a given input tilt to the whole suspension, therefore, we can work out what the input tilt is at each mass and hence at each wire-clamp junction. From there we can work out what the associated torque is at each junction. Using the matlab model of the suspension we should thus be able to find the residual tilt effect we would expect on the whole suspension. This prediction can be compared with observations.

2. RESIDUAL TORQUE MAGNITUDE

The restoring torque on a pendulum with length “d” is simply

$$T = mgd \sin(\theta) \approx mgd\theta \text{ for small } \theta$$



For example, with a 14mrad residual pitch and a d distance of 1mm, the residual torque is

$$T = mgd\theta = 40 \times 9.81 \times 0.001 \times 0.014 = 0.0055 \text{ N.m}$$

3. PREVIOUS RESULTS

3.1 Getting from frequency to “d” distance

In previous tests we measured the tilt frequency and used this to infer the “d” distance. We extrapolated from an assumption that the initial “d” was 1mm, using the relationship $d \propto f^2$. However, knowing the dimensions of the mass we can calculate its moments of inertia and calculate d directly from

$$f = \frac{1}{2\pi} \sqrt{\frac{k}{I}} \text{ where } k \text{ is the torsional stiffness in Nm/radian, from}$$

$$k = \frac{T}{\theta} = mgd$$

Inverting the above gives

$$\frac{mgd}{I} = (2\pi f)^2, \text{ hence } d = \frac{I}{mg} (2\pi f)^2$$

From the matlab model we know that the mass moment of inertia about the horizontal axis I is 0.3 kg.m² (parameter I3y in the model).

So, for a measured period of

3.2 0.71mm diameter wire from T080033-00-K

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

	Period from T040033	Calculated d distance from equations above (mm)	Range of output in mRad corresponding to input of +/- 125 mRad	Torque for 250mRad input N.m	Torque for 100mRad input
Test mass on its own,	5	1.21	14	0.0066	0.0027
With extra 800 g	3.5	2.46	5.3	0.0051	0.0020
With extra 1600g	2.7	4.14	4.3	0.0070	0.0028

3.3 1.1 mm diameter wire from T080044-00-K

The frequency was 2.5Hz, giving the numbers below.

	Period from T040044	Calculated d distance from equations above (mm)	Range of output in mRad corresponding to input of +/- 11 mRad	Torque for 22mRad input N.m	Torque for 100mRad input
Test mass on its own,	5	4.83	0.14	0.0003	0.0012

3.4 Conclusions on torque and effect of wire diameter

The results from the thin wire suggest an effect of order ~ 0.0025 Nm output per 100mRad input. The result for the thick wire shows that a thick wire is better when it is supporting the same load as the thin wire. How a thick wire behaves when it is more highly loaded we cannot say, and a test would be hard.

For the time being I will assume that all wires behave the same – this is not such a key assumption as may appear. The wires impact the masses as follows

Mass	Wires from above	Wires going down	Wires per mass			
			1.05mm A	0.71mm B	0.63mm C	0.46mm D
Top	2*A	4*B	2	4		
UIM	4*B	4*C		4	4	
PUM	4*C	4*D			4	4
test	4*D					4

Sixteen of the 26 wire/clamp interfaces are made by wires of 0.71mm or 0.63mm diameter.

4. PROPOSED MODELLING WORK

Start with the standard parameter set.

For a 10mRad input motion we would expect to see an output torque on every wire/clamp interface of $2.5E-4$ Nm. From earlier work we know that 0.035 N.m of input torque gives 10mRad at the UIM and that 0.3N.m gives 100mRad – so there is a weak non-linearity above $3.5E-2$ Nm. I imagine that we can assume linearity at much lower torques, which would be useful because from a small set of model runs we can experiment with the numbers.

I propose the following five runs:

1. Input torque of $1E-3$ Nm at the top mass.
2. Same at the UIM
3. Same at the PUM
4. Same at the TM

This should allow us to concoct various combinations of input torques. To check this assumption, and to look at a typical input set, try

5. Input torque of $1.5E-3$ N.m at the top mass and $2E-3$ N.m at the UIM and $2E-3$ N.m at the PUM and $1E-3$ N.m at the TM.