Interim report on the Target Shaft mechanical analysis and assessment -- FEA

By Stephanie Yang

The aim is to examine how the mechanical force (bending or twisting of the shaft) travelling at high speed could affect the integrity of the shaft itself or the bearings that guide its movements.

The FEA model (Fig 1) includes a full length of the shaft, the two supporting bearings and the magnet.

The step that we are taking is:-

1. Calculate the force that requires to bend the shaft to the extent that it takes up the gap between the magnet and the coil. We then work out how much would each bearing sees:-

   This is by exerting a unit lateral force (1 N) on the magnet, causing it to bend. We then work out how much it bends and pro-rata that number to match the gap between the magnet and the coil. The FEA result shows that for a 1mm annulus gap, the that force may be about 80N. The lower bearing may take up 2/3 of this 80N when it is in the down position.

2. Estimate the twisting moment on the shaft. We then work out how much force would be exerted on the shaft fins at the lower bearing region.

   We need the magnet force results to estimate the twisting moment. As for our part, we will again use a unit twisting moment to see what impact it will have on the shaft fins.

3. The force produced by the vibrating of the lower part of the shaft (the target end).

   This could be caused by the resonance effect of the lower shaft when the magnet is being “bashed” about from one side of the coil to the other. The natural frequency of the shaft has been worked out last time. We want to see how it behaves if there is a vibrational force from the magnet. This could produce some reaction force on the bearings

4. Same as (3), but looking at the same effect caused by the vibrational behaviour of the upper part of the shaft.

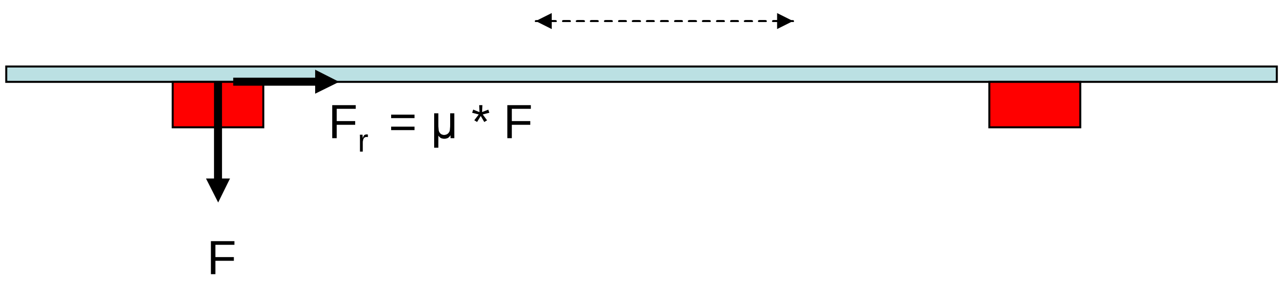
5. Effect of tilting on the shaft. This is caused by the gaps between the upper and lower bearings. The force comes from the inertial effect of the magnet. The horizontal component from this force is not insignificant.

The FEA model will help us establish what the individual forces are.

There may be other forces that we have missed out in here. Chris Booth and his team at Sheffield will be able to advise.

All these forces that press on the bearing all the time when the shaft is travelling up and down will convert to a frictional force. Our aim is to convert the energy generated from this frictional force to see how much heat is generated as a result.

As a rough guess



*Heat generated by the frictional force (W) = Fr * total distance travelled in one cycle / time taken for 1 cycle*

For a total force of, say, 100N on the bearing surface and taking μ = 0.6

Flight distance is about 140mm per cycle, and time per cycle is 0.01 sec (???)

*We have W = 100 *0.6 *0.14 / 0.001 = 840 W.*

The shaft may not dip 100 times a second and we may not have the full 840W generated continuously. But it does show that the heat generated is not insignificant!

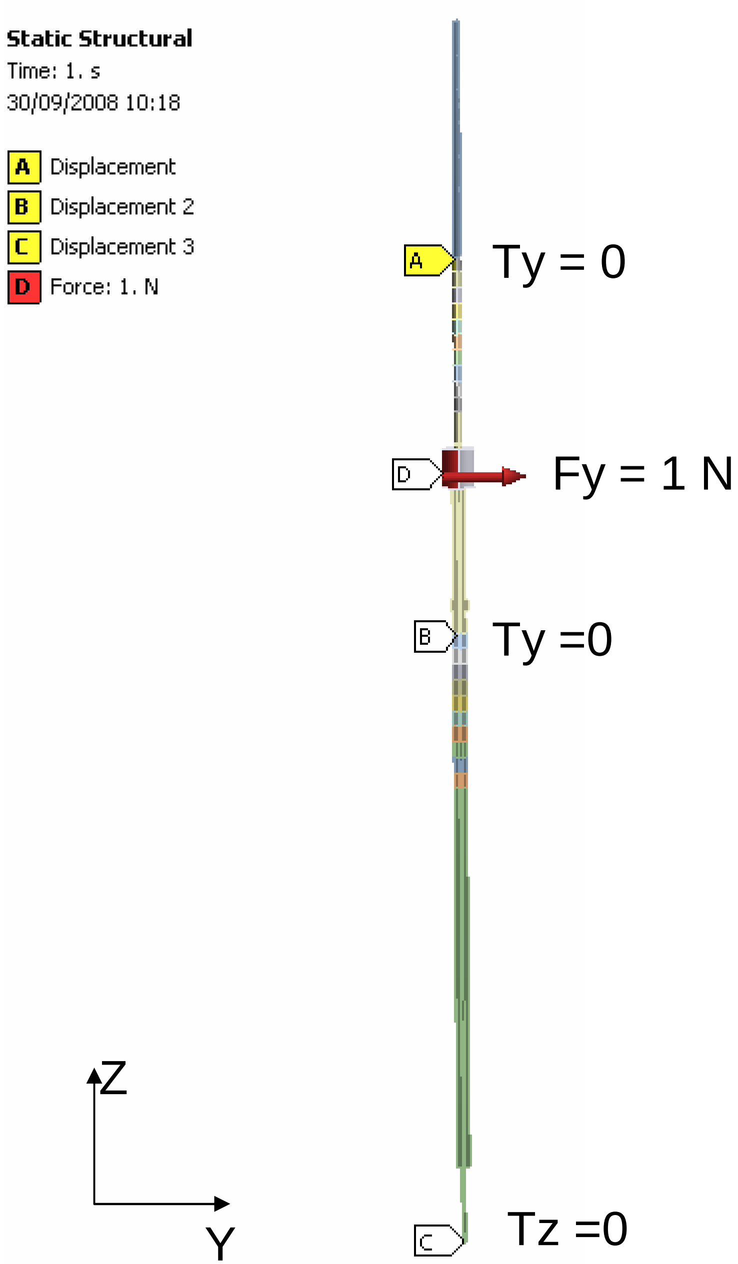
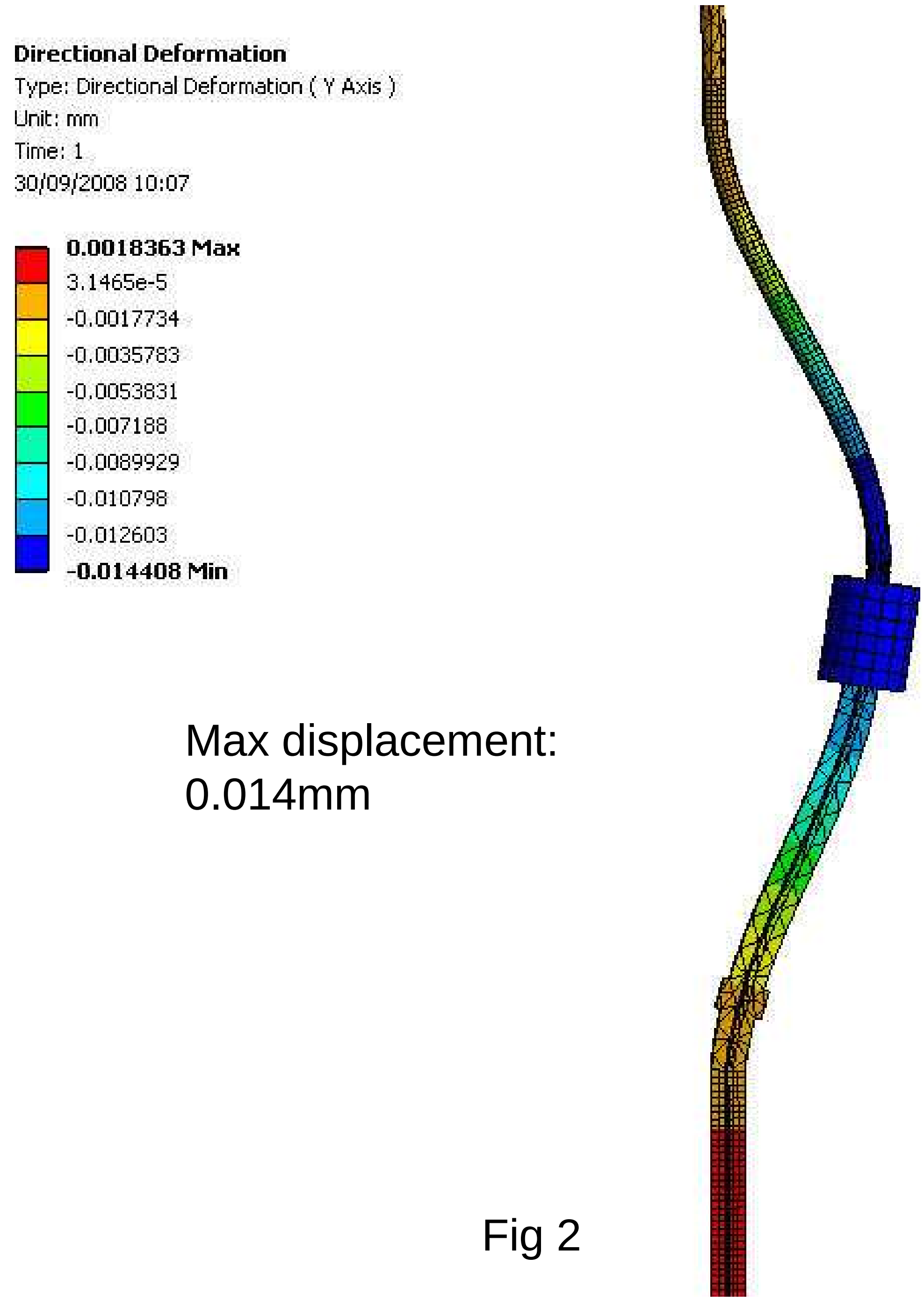
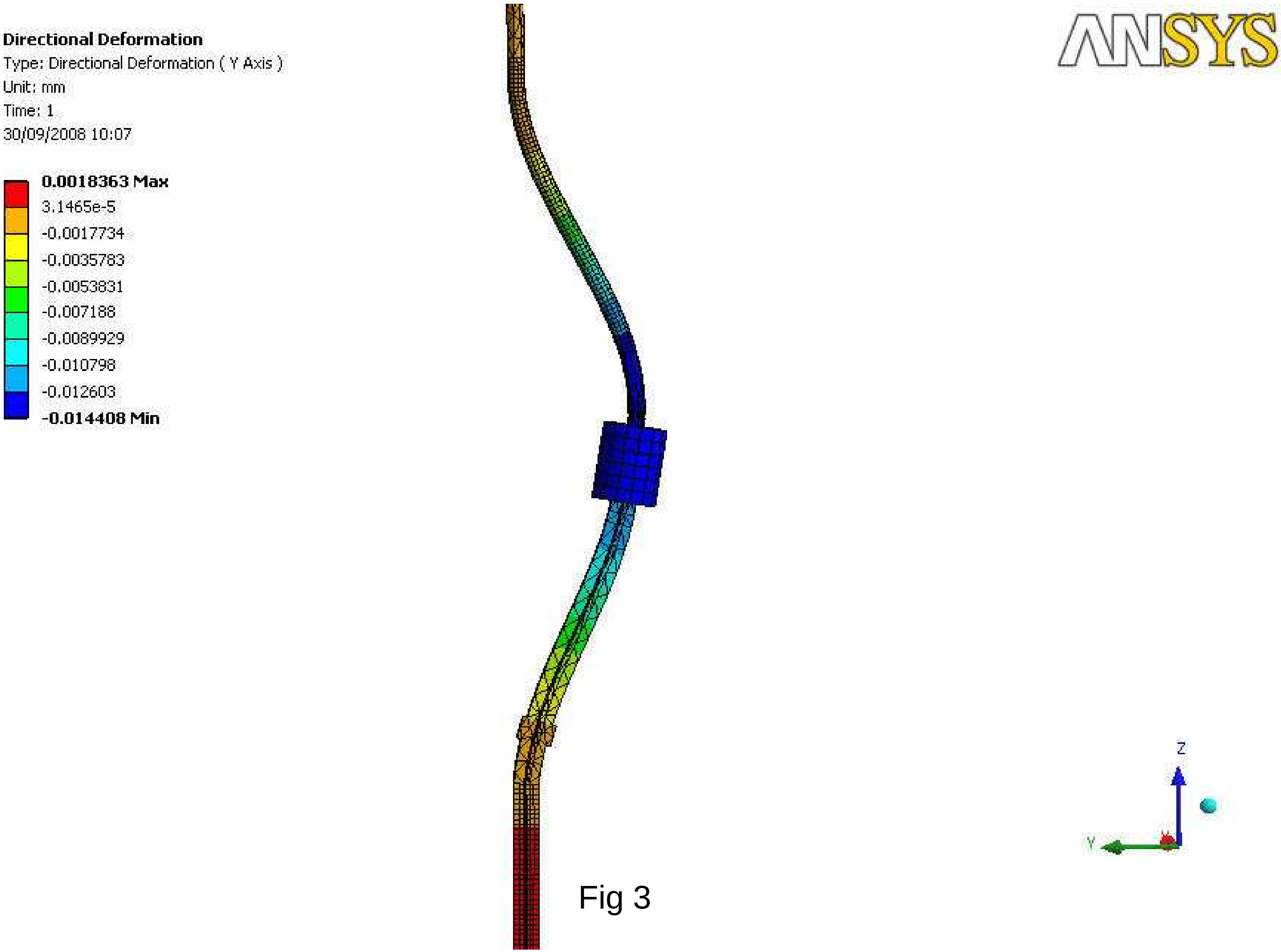


Fig 1
Boundary conditions



Max displacement: 0.014mm

Fig 2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Unit: mm
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-0.0035783
-0.0053831
-0.007188
-0.0089929
-0.010798
-0.012603
-0.014408 Min
ANSYS
Z
Y

Fig 3