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Mode Cleaner Top Blade Rotational Adjuster Design

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Revision 01: With comments from CIT, AG added 15th June 2004

1. Introduction

The Rotational Adjuster for the Mode Cleaner Top Blade[1] is used to correctly align a suspension within its structure. During the assembly and suspension of a triple pendulum chain, it is possible that the lower mass can end up angled slightly in the x-y plane. In suspensions that use the space-saving crossed-blade layout, it is difficult to physically see if the blade tip alignment is accurate and thus some level of adjustment is required.

2. The Mode Cleaner Rotational Adjuster Design

To correct this angular (yaw) offset an adjuster has been designed that will move the blade tip in a range of +/-3mm from its default position to ensure the accurate positioning of the blade. The rotational adjuster, shown in the picture below, was chosen for several reasons:

- The blade could be moved whilst under load;
- The mechanism had to fit on a limited space at the top of the existing mode cleaner structure and could not interfere with the opposing crossed blade (or attached wire);
- As opposed to other concepts, movement in the x-direction was maximised whilst being kept to a minimum in the y-direction and thus it was more accurate at repositioning the blades at the break-off positions.
- The whole mechanism could be removed should the suspension design exceed the mass budget.
- The mechanism could be easily designed out should such levels of adjustment not be required in the final design.

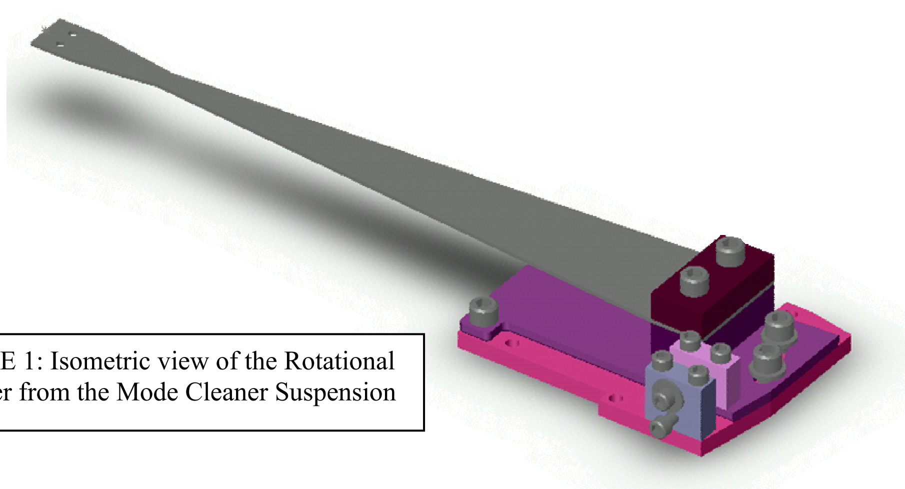


FIGURE 1: Isometric view of the Rotational Adjuster from the Mode Cleaner Suspension

[1] D030451, Advanced LIGO, SUS, MC Upper Blade, Rotational Adjuster Assembly

3. Design Considerations for the Rotational Adjuster

3.1. Positioning of pivot bolt

The pivot bolt was placed on the y-axis of the suspension – in-line with the blade break-off points – as this was deemed the optimum location such that the blade tip moved primarily in the x-direction and rather than in the y-direction. The pivot bolt was placed approximately 2/3^{rds} of the way along the blade[2] to:

- Avoid the blade tip of the opposite crossed blade
- Allow for clamping to the geometry of an existing structure (which you will notice has a large cut-out on it – Diagram 2)
- Distribute the forces on the plate through the blade clamp as effectively as possible.

The following diagrams and calculations show the relationships involved.

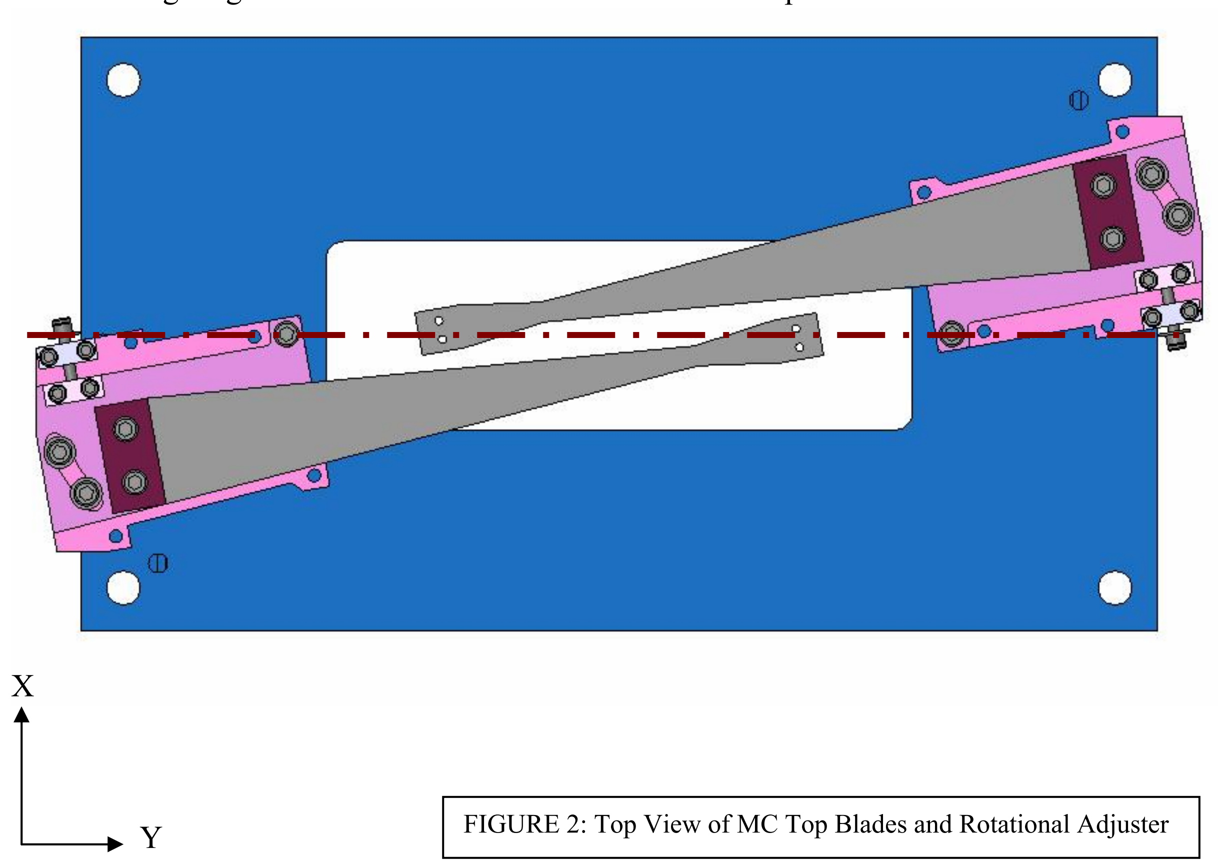
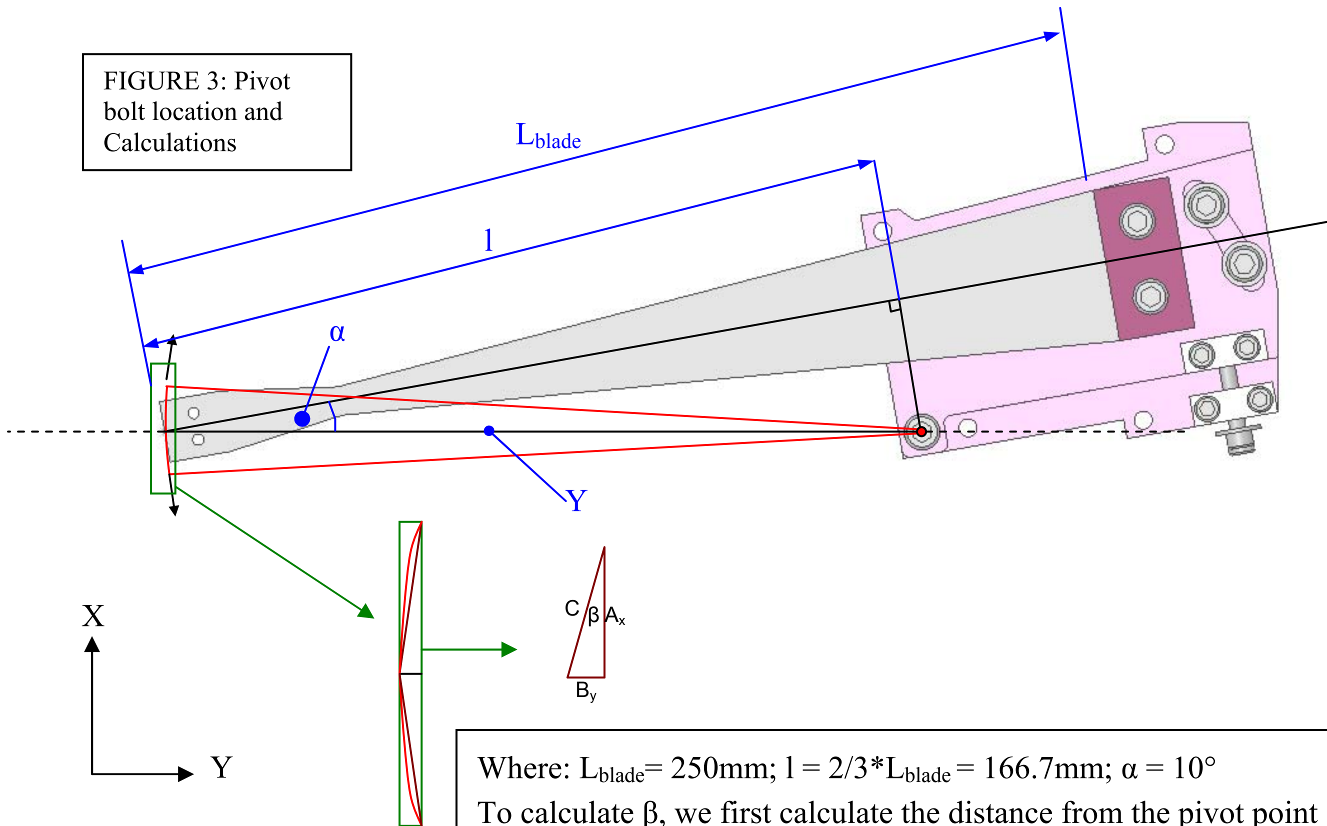


FIGURE 2: Top View of MC Top Blades and Rotational Adjuster

[2] The mode cleaner pivot point actually ended up closer to 4/5ths of the way up the blade rather than 2/3rds. This was due to it having to fit on an existing structure.

FIGURE 3: Pivot bolt location and Calculations



Where: L_{blade}= 250mm; l = 2/3*L_{blade} = 166.7mm; α = 10°

To calculate β, we first calculate the distance from the pivot point to the blade tip: Y= 166.7/cos10° = 169.3mm.

Rotational path circumference = 2*π*r = 2*π*169.3 = 1063.7mm.

Hence, β = 360*(3/1063.7) = 1.015°.

Assume that in the range +/-3mm the rotational path is approximately straight i.e. C = 3mm.

The displacement in X-direction,

A_x = 3*cos1.015° =2.9995mm

The displacement in the Y-direction,

B_y = 3*sin1.015° = 0.053mm

As can be seen from the calculations in the box above – the location of the bolt pivot hole at this point minimises the y movement to less than 1.8% of the desired x-movement[3].

[3] If we took the pivot point to be at 4/5ths of the length of the blade, as stated in footnote 2 is true of the mode cleaner design, we would attain the following values: Y=203.1mm; β = 0.85°; A_x = 2.9997mm; B_y = 0.0445mm. Therefore, the resulting y-movement is 1.5% of the x-movement.

3.2. Positioning of Push/Pull mechanism

The push-pull mechanism is located on an arc centred about the pivot bolt. The mechanism itself was then located at a convenient point such that the unit was compact and so that access to the bolts was good.

The top pull-bolt runs through an oversized clear hole in the push block (lower block in the diagrams) and threads through the pull block. This is so that as the plate becomes angled slightly the bolt still runs freely despite the obvious angle that has been created.

The pull-bolt pulls against an oversized washer in the push block and is threaded into the pull block.

The push-bolt threads through the push-block and then simply pushes against the moving plate of the rotational adjuster.

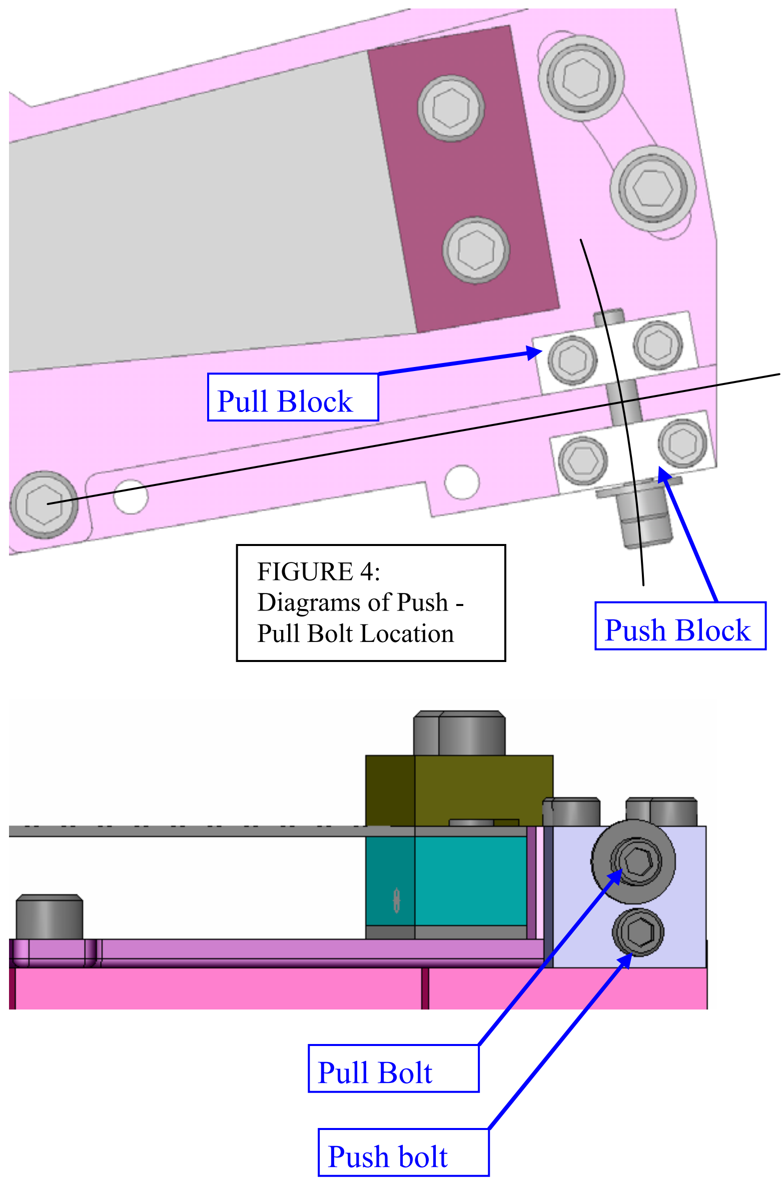


FIGURE 4: Diagrams of Push - Pull Bolt Location

3.3. Positioning of the clamping bolts.

The clamping bolts again are on an arc centred about the pivot bolt. In the mode cleaner design, both bolts are on the same arc, each bolt could however - given the appropriate space - be on two separate arcs of differing radii. The bolts shown here fasten into the fixed mounting plate.

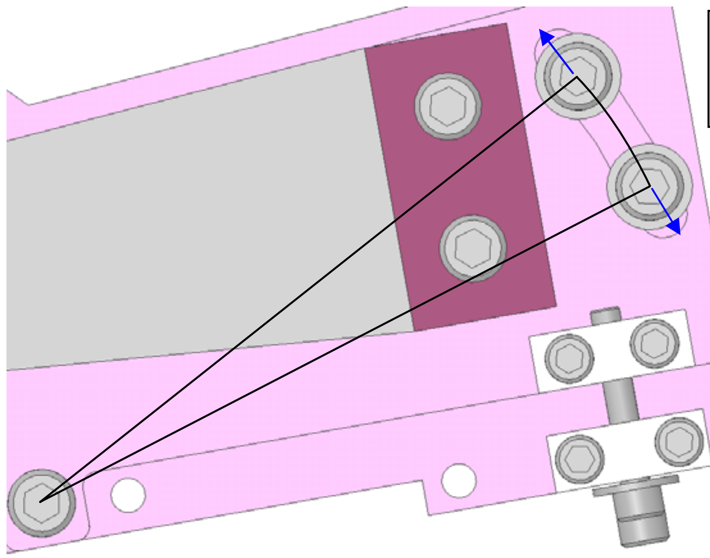
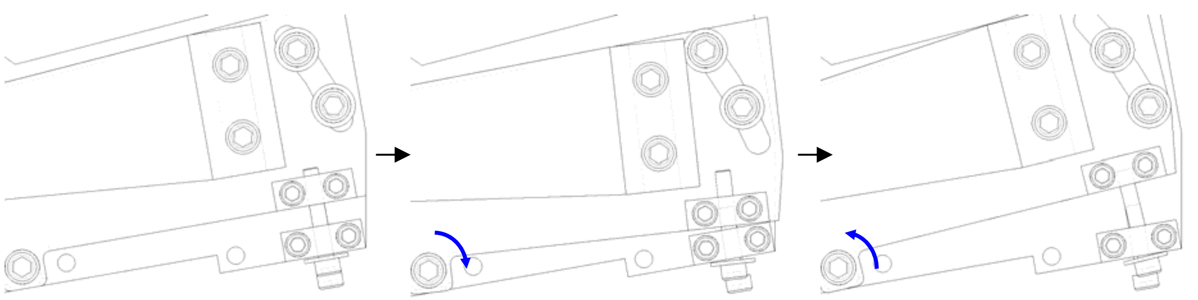


FIGURE 5: Diagram of Clamping Bolt Location



3.4. Forces on the bolts/rotating plate.

Using the following model we can show how the force on the blade is translated to the bolts and the rotating plate.

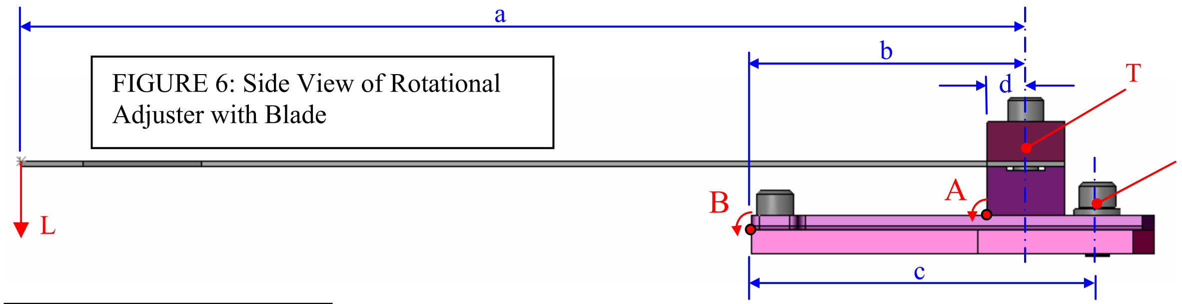


FIGURE 6: Side View of Rotational Adjuster with Blade

a = 260mm
b = 69.9mm
c = 88.1mm
d = 10mm
L = 58.86N
T = Tension in Blade Clamp Bolt
t = Tension in Rotating Plate Bolt

Moments about A: L * (a - d) = T * (d)
Moments about B: L * (a – b) = t * (c)

T = (58.86 * 250) / 10
T = 1471.5N (i.e. 735.75N per bolt)

t = (58.86 * (260-69.9)) / 88.1
t = 127N maximum (i.e. 63.5N per bolt)

3.5. Other Design Considerations

- The design was kept as a complete separate unit to allow this to be designed out if it was seen to be an excessive level of adjustment – as we are only at the prototype stage we do not have firm ideas of the levels of adjustment required in these suspensions.

- The material chosen for the rotating plate (the upper of the two plates) was Stainless steel and this rotated on a base plate (that attaches to the suspension structure) manufactured from aluminium. The reason for the choice of stainless steel for the rotating plate was because the bolts through the blade clamps would thread into this plate and it would thus have to take the majority of the stress. The plate would in turn rotate on the aluminium base plate which was aluminium to offer a lower coefficient of friction when used in clean environments.

- All of the lower edges of the rotating plate were radius-ed so as to stop the Stainless steel plate gouging material from the softer aluminium plate when moved – important to stop the occurrence of filings in a clean environment.

- The edge at the front end of this removable unit is at right angles to the blade, this is so that the force transferred from the blade is distributed evenly across this edge.

4. Conclusions

This rotational design was deemed the optimum in terms of ease adjustability, ease of attachment on an existing design and accuracy of keeping the distance between both blade tips as close as possible to the separation specified by the MATLAB Triple Suspension model.

The rotational adjuster for the Mode Cleaner was designed following the manufacture and test of an early bench prototype at Caltech (Figure 7).

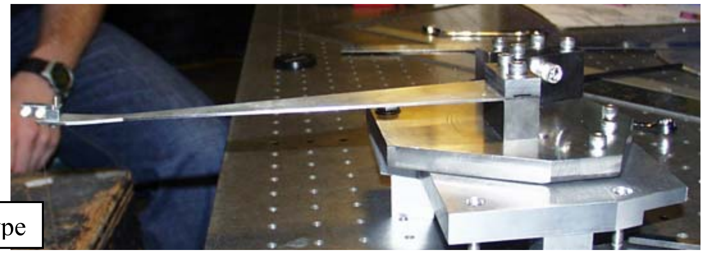
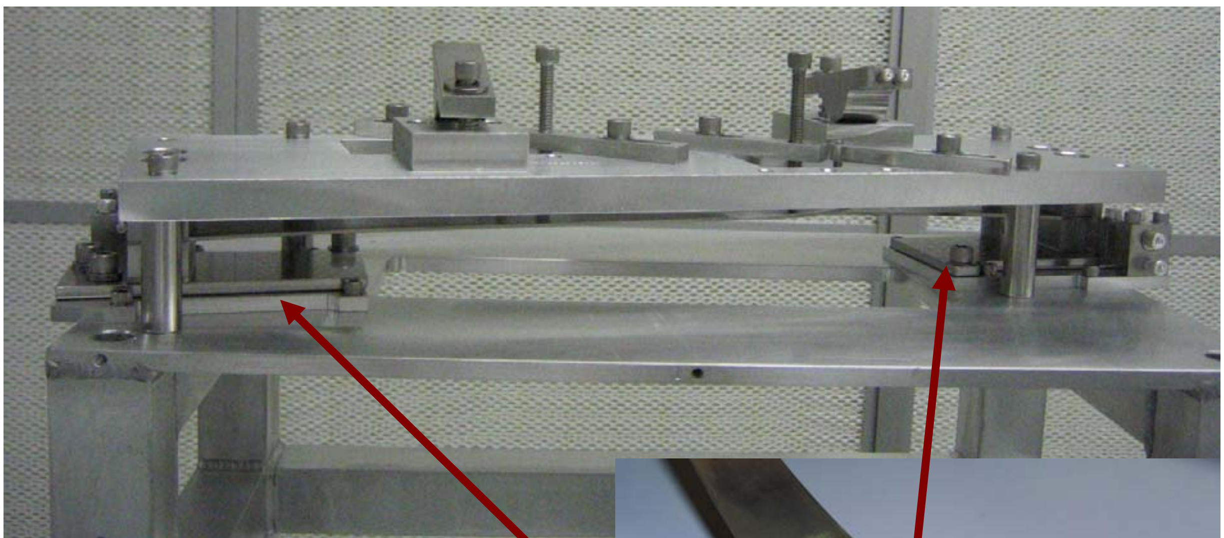


FIGURE 7: Rotational Adjuster Bench Prototype

The design was then integrated into the existing Mode Cleaner assembly and has since been successfully tested in clean room conditions (Figure 8).



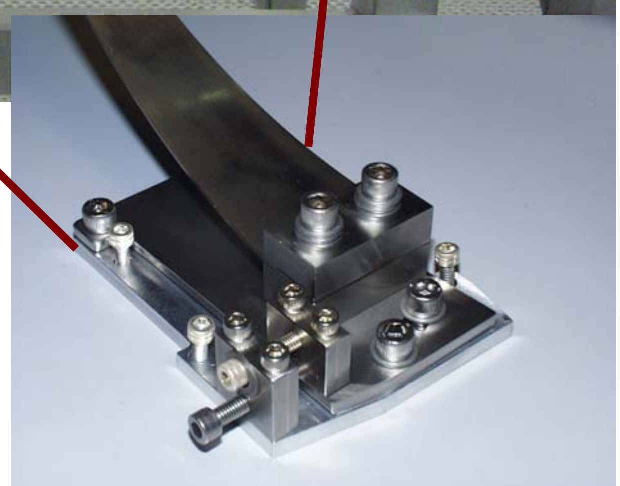


FIGURE 8: Mode Cleaner Rotational Adjuster for the controls prototype installed in clean conditions.

5. Next Steps

- The design may be scaled up for use on the future RM and ETM Quad designs. Care should however be taken during the design of the parts so that they will offer the correct strength so as not to buckle under the greater loads apparent in the larger suspensions.