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Latest Update: 6 Feb 13

Comet C/2012 S1 time lapse photo goes on Astrophotos Page 3.

EQ6 Blog updated

My EQ6 Project

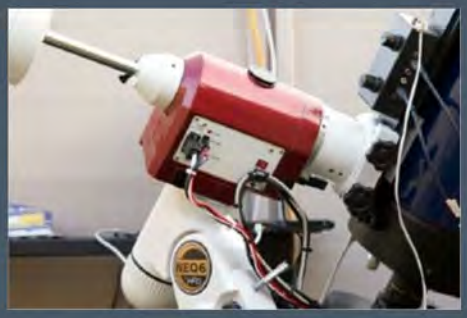
Having yearned for an equatorial mount with a small and smooth periodic error, I finally accepted that I couldn't afford a Takahashi or Astro-Physics mount, so in April I took a chance and bought a SkyWatcher EQ6 pro from FLO.

It's performance out of the box wasn't a disaster, but the noises it made, both when setting off on a slew and stopping, was enough to make anyone with a decent amount of mechanical sympathy cringe!

So I stripped, cleaned and rebuilt it with the aid of astro-baby's excellent guide, and in spite of about 20 attempts to improve the gear mesh, it was pretty much the same, so I decided to convert it to belt drive as shown over the next few pages.

I've gone a bit further than many, but the initial results look quite promising. And all you can hear are the stepper motors spinning up and down.

Get a coffee, there's a lot of info here. - I have updated this section to show how I removed the play in the counterweight shaft, well I needed to use my new lathe for something other than just the belt conversion.



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My EQ6 Project - Page 2

I gathered as much info as I could prior to starting this project. Thank God for the interweb. A few guys had tried this already, most seemed to pick a 12/48 pulley combo, as it avoided the need to do any work on the case of the mount. Unfortunately, the 12 tooth pulley which goes on the stepper motor has to be bored out to 'within an inch of its life' to fit the 5mm shaft, and this had led to a high percentage being slightly out of true.

Some seemed to think that the belt would work around this, which is rubbish of course. It may not bind and stall, like a gear, but any cam-like motion will introduce additional harmonics into the PE curve. On the RA worm itself, this can be addressed (to a point), but errors at the stepper motor would be much harder to gloss over. The absence of PE traces from 'before' and 'after' also made me suspicious that this hadn't worked for everyone.

Therefore I went for a 15/60t aproach. The 15 tooth stepper pulley bore is bigger, so only the worm pulley needed significant machining. (Good excuse to buy a lathe...)
Opening out the bore of the 60t pulley to 12mm, taking a couple of mm off the outer face and boss, and turning the boss diameter down to approx 20mm seemed to leave me with a kitchen full of swarf and a less than happy wife! She got over it.

Then I went to work on the case. To be fair, none of this is essential, but I'm a bit of a belt and braces type. The Declination worm housing had a definite lip which might have interfered with the pulley, so I smoothed this down with a dremel. I also drilled an 8mm hole in both worm housings to view the belt on the pulley. That way I could adjust the motor pulley to place the belts exactly in the centre of the worm pulleys (and take a measurement).

To be fair the metal is very soft so this isn't hard at all

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To make sure the belts weren't rubbing on the case, I also used a round file to open up the RA and Dec belt apertures in the main housing by about 1-2mm at each end (to a length of 42mm centred on the notch). This is easier to see than explain, so the photos are below. I also took a little off the sides (1mm) with a flat file. Again, because the metal is so soft, so this can be done by hand in about 5 minutes.

Because I'd read stories of people struggling to get the belts over the motor pulleys during the rebuild (it is done blind), I decided to get a bit more heavy handed with the main case and open it up over the stepper motor pulleys.

This was by far the biggest job, but it makes it really easy to check the belt tension. To be honest, as long as you lever the motors out against the belts during installation, without going mad, they should be fine. If you set the belt too tight, the stepper motors may stall (no drama). If you let them slip, you could damage them.

If you're wondering not just about the apertures, but also where the bulges have gone, well... Its amazing what you can do with a pillar drill and a milling cutter. I have to say that I almost regretted attempting this without a proper milling machine. Gently sliding the case to and fro, while taking about 0.2mm off with each pass, wasn't much fun, especially when the milling cutter caught and pulled the case out of my hands! Would have been safer, and not much slower with a hand file.

I wanted a flat surface here so I could put a cover over the openings after I'd finished trying to find the best belt length and developing the mod. If anyone else does this I would recommend just drilling a couple of 12-20mm holes to make it easier to fit the belts, and then tape over them. Or you could find a machine shop to mill this surface flat. I drilled three holes for each opening, cut between them with a dremel and then used round and flat files to form these shapes. I also filed a bit off the inner corners on the other side of the case, from where the PCB fits into the case, to ease the installation and removal of the controller card.

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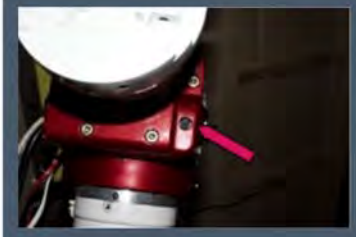
After washing out the cases, and giving them a prime, colour and lacquer, it was time for the rebuild.



The machined 60t pulley goes on the worm (don't forget the belt). There should be just a slight (0.5mm) gap between the pulley and case, this will stop the belt coming off if your motor pulley is a little too far out. You can then rebuild as normal. Finally, the 15t motor pulleys goes on (10-10.5mm along the shaft worked for me), and the motors go in. With the right belts, the motors should go in at an angle and pick the belts up as you straighten them, but having a hole in the main body over the stepper motors is a big help here. If you have the openings, you can tension the belts by inserting a flat screwdriver from the front, otherwise you'll have to do it from the controller panel side. I set the belts to have about +_2mm of give at the mid travel point.



Then I ran the mount for a while, looked in through the 8mm belt inspection holes to make sure the belts were centred on the worm pulleys, (had to move the Dec stepper pulley inwards from 10.5mm to 10mm along the shaft, as this belt was on the edge of the worm pulley rather than having 0.5-0.75mm each side) and then just taped over the holes.

I then cut some 3mm perspex and frosted it lightly with fine emery paper to use as a cover over the new openings. At 3mm thickness, it matches the depth of the bulges on the worm housings which I had machined off before forming the holes. I had drilled and tapped some M3 holes in the case to secure this already (doesn't really need 4 though!).

If you're happy to take your time with the motor installation, all you'd need to do is spend 5 minutes filing to open out the slots in the cases and take off any rough edges. Then you'd be good to fit the pulleys. This would save you having to paint anything (I would recommend washing the cases out though).

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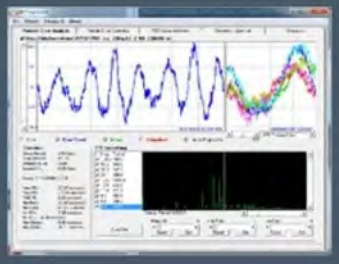
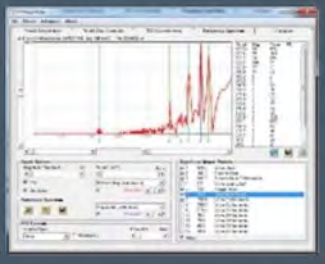
Why did I want to do it? Well look at my PE before. The trace below is the best I recorded, with just an 80ED mounted. My PE was about +20 -17, which in magnitude terms is ok, but it was very uneven and there were loads of high frequency components from the gears, which you just can't guide out. This gives astrophotos which are ok, but just look soft (unless you're happy to just use a camera lens at about 9 arcsecs per pixel - the noise is about 6 arcsecs pk-pk).

With an LX90 OTA on board, the PE was about +-27 with a max rate of 10 arcsecs/S. The FFT spectrum (below right) showed the transfer gear doing more damage than the worm! There was also a big spike from the stepper gear. The 4 main spikes from left to right are:
stepper gear, worm 2nd harmonic, transfer gear and worm fundamental, there is also noise from the gear mesh at 10.2s.

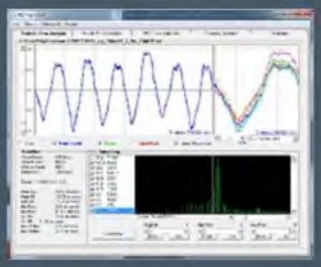


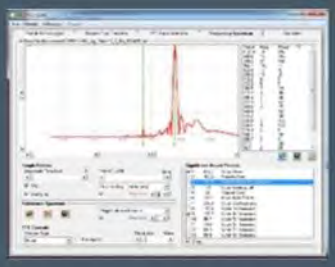


Below on the left is the trace from my 2nd run with the belt conversion (will explain later) and the right screenshot is the FFT spectrum, only showing the worm fundamental at 478s. The PE is +-23, but the max rate is only 2 arcsecs/S (close to seeing limited)
(Note, the worm 4th harmonic is now ambiguous with the stepper pulley component as the drive ratio is now 4:1.)

And this trace was taken with a gusty wind blowing the shed around! (Scope tripod on the shed floor).

Before you say 'but I've seen loads of standard mounts do better!', please note that there is no 'low pass' or 'auto' filtering applied here in PECPrep, these are raw plots and the mount is carrying about 11kg.





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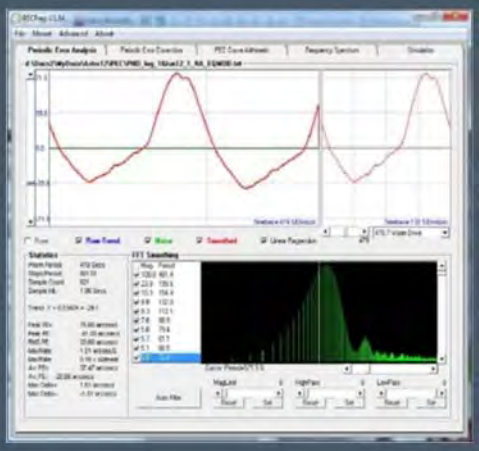
EQ6 Blog updated

My EQ6 Project - Page 6

In case anyone is wondering why I didn't show my first PE trace, well it's because it was awful. (Lovely and smooth but +76 to -41!)



While I was disassembling the RA Worm on the initial strip down, my hex driver head sheared off in the worm gear grub screw. So I had to cut the gear off the worm. As it was brass, I just cut a line in it and opened it up with a cold chisel, but in the process I marked the RA worm quite badly. To be honest, I didn't worry about this, as I just planned to swap it with the dec worm.

Big mistake. The dec worm was out of true. So I stripped the mount and swapped them back. (To be honest, this might have guided ok, as the max rate was 1.5 arcsecs/sec).

So I believe that the mount could be even better, as it is now running with a carelessly damaged RA worm. I have ordered an aeroquest worm and will let you know how it goes. While I wait for it, I will continue trying to get the PE down by experimenting with the worm engagement.

If you watch the video clip by clicking here and listen when the dec motor runs, you will hear a slight rhythmic binding from the Dec worm, with no such noise from the RA axis. (apologies for the background noise, but I had to turn the mic gain up).

So there is a good reason why the manufacturer had originally fitted that worm in the Dec position.

My mount has gone from bothering the neighbours to near silent, so I'm pretty happy.

Get in touch if you want to have a go. I can provide a machined kit of parts with about a two week lead time if I don't have stock. Maybe I can recoup some of the lathe cost..

This is for EQMod users only because of the ratio

This mod isn't quite as cheap to do as the 12/48 version. The stepper pinion alone is 18$, plus shipping and taxes, so kits (modded stepper and worm pulleys, and belt) would be 60 quid per axis or 110 for both.
But I reckon you could get down to a super smooth PE, magnitude no more than around +-20pk-pk with a decent original worm (which is G11 territory). PAGE 7 is new, and shows the aeroquest worm. - Pre-install.

Admin@alphageek.co.uk

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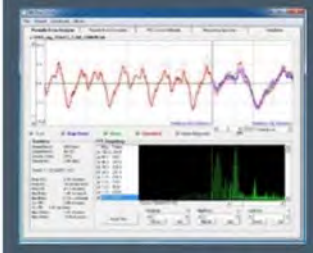
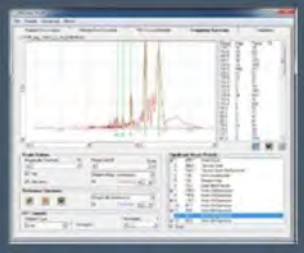
My EQ6 Project - Page 7

Over the past few weeks I have been continually tweaking the RA worm/ring engagement. The lowest amplitude PE curve I have seen is below. Believe it or not, the magnitude of this is just +8 to -10 ArcSecs, but the damage I did to the RA worm really shows now.

If you open the photo on the right, you can see the indentation along the 6 or 7 threads along the right hand side of the worm. I'm pretty sure this is generating the kick in my PE. The FFT now shows all the even worm harmonics, with the main peak being the 2nd harmonic, which is not ideal.





Well, I've now had a few attempts at fitting the pulley to the aeroquest worm, getting the runout down to 0.04mm in the end. The motor pulley runout is also no more than this, so was hoping for some good results.

Unfortunately I don't have them yet, the result is very similar to that shown above left! So I'm thinking that the worm may not solely be responsible for the 2nd harmonic. Don't get me wrong, it's way better than a geared EQ6, because the gear mesh components have gone from the PE trace (no more 4 arc sec 0.1Hz wobble superimposed on the PE).

So I have scoured the forums and seen that asymmetry in the PE graph is quite common, often with a rapid change of direction at one end, with a hesitant change at the other. So I am now in the process of trying both combinations of ring gears with the worm, and then I'll be trying to lap worm and ring gear in the mount.

Will see how that goes.

Pages 8, 9 and 10 show a few tips for tuning, a counterweight collar sleeve and my tweak to stop bending altitude adjusters!

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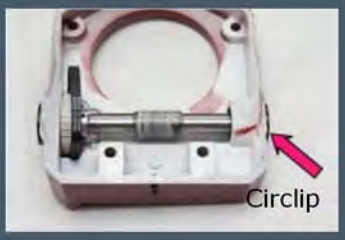
My EQ6 Project - Page 8 - Tuning

The AstroBaby tutorials are an amazing piece of work, but I believe you can improve on these procedures in a two key areas to make the mount perform optimally.



First of all, the worm bearing tension, set by those horrid threaded slotted circlips, should be set before you fit the worm housings to the mount. Fit the pulley-side end cap fully, then spin the worm by hand and tighten the adjustable circlip with your circlip pliers until you feel it just start to generate resistance as the worm rotates. At this point you will have no float, but the worm rotation should still be smooth, without binding.

If you leave these loose until after rebuild, you will then have 2 variables affecting backlash - worm/ring gear engagement and worm bearing end float, not helpful.

The worm to ring gear meshing is not easy to set perfectly. Juggling those two hex set screws takes time, and sometimes a bit of trial and error.

First off, try to make sure that the entire worm housing is square. Compare the 4 sides of the housing with those of the main body of the mount and try to get this straight as you initially tighten the set screws. Adjust the 2 set screws to start with to deliberately achieve about a small amount of backlash in the axis you are adjusting. At this point make sure the 4 bolts securing the worm housing are just secure but not tight.

Then, slip a short piece of 10mm hose over the end of the worm which sticks out proud of the circlip (I used a tie-wrap to make it grip properly). At this point you should be able to spin the worm easily by rotating the hose (your motors should not be fitted yet of course).

Gradually increase the engagement adjusting both small set screws (one to tighten, one which fights it) until the hose slips on the worm (rather than turning it). At this point the worm is binding on the ring gear. Then back off the set screw which pulls the worm housing, and therefore the worm, onto the ring gear, by about 1/16 of a turn.

Now see if you can turn the worm again. Keep adjusting until you can spin the worm with the hose without binding. You should then have the least backlash possible without binding of the gears. Keep tension on both set screws, so that tightening or backing off one by just a fraction generates slight movement of the housing (and worm).

If you still have gears in your mount - Unlucky. Changing the worm engagement means moving the worm housing, which means changing the mesh between the transfer gear and the one on the worm. This may then mean you have to reset your motor pinion engagement.

The best thing about the belt conversion is that you can now adjust worm to ring engagement without creating binding in your motor pinion/transfer gear train, and tension the belt without affecting worm engagement.

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My EQ6 Project - Page 9 - Counterweight Collar Sleeve

One aspect of the mount which has always niggled me slightly is the play in the counterweight bar. This wasn't huge by any means, but meant that the bar end would sometimes suddenly drop by 2 or 3mm during slews, as the weights pulled the bar down.

I thought that machining a sleeve to tightly fit the bar, and boring out the existing counterweight collar to take the sleeve shouldn't be too difficult.

The sleeve and bored out collar is shown on the right, and the full assembly below.

To really beef it all up, I drilled and tapped 3 holes in the old collar to take M5 hex head bolts, but to be honest they're not really necessary to hold it all together, as I turned the parts to be a slight interference fit.

But guess what, no more slop, and no sudden shifts during slews.

Will be a bit surprised if replacement collars don't start springing up soon, but I think it took me a bit too long to make it, to be viable as an upgrade.

Pretty sure any machinist could do this in a couple of hours.

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My EQ6 Project - Page 10 - Latitude Adjustment/Bolts

Come on, who has an Eq 6 and thinks the latitude adjustment mechanism is up to the job? Pretty sure there's a reason why loads of people sell stronger bolts for this.

But I don't believe the bolt material is at fault. Instead there is an obvious flaw in the design for anyone who lives further north than about 20 degrees of Latitude.

The image to the right shows the mount with the side plates removed (and in the bin as they were in 3 pieces by that point), and shows the bolt approach angles.

The photo left, shows how the bolt which increases latitude pushes at a tangent to the surface receiving the pressure. This means the bolt is easily bent, as it is being forced down as you attempt to raise the polar axis.

The simple solution here is to separate the two parts, drill a depression around 8mm dia and 3-4mm deep where the mark from the bolt tip is seen. It is quite important that you drill at an angle close to that which the bolt will approach the driven surface. Hopefully you can just make this out on the right.

The pics below show how the tip of the latitude bolt is now held in place by the recess. The hole is just deep enough to stop the bolt slipping down. I could have gone deeper here, to be honest, but this is enough to do the job. The load is now applied orthogonal to the bolt axis.

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My EQ6 Project - Page 11 - Belt Conversion Kits

As I've explained, the EQ6 gear train seriously limits the mount's imaging potential. Everyone wants a PE like this one on the right. 5 arc secs peak to peak, almost nothing with PEC applied.

But you could image quite well with a PE going from +20 to -20 arc secs, with decent autoguiding. The guide cam picks up the error and corrects it before it has allowed your stars to spread over too many adjacent pixels.

But an autoguider can't provide updates quickly enough, and the mount can't correct quickly enough to cope with high frequency noise superimposed on the worm produced periodic error. This is what you get from the EQ6 gears.

By the time it's correcting, the mount has already changed direction. This gives you photos which look out of focus, or worse.

The Belt drive conversion won't take you from curve 3 to curve 1, but it should get you to curve 2, which you can then guide out...

I've had an unfortunate experience recently, when a chap ordered a kit, and supplied his worms so I could ensure the pulleys were a tight fit and well centred. I took great care, turned the order around in an afternoon, only to be accused of swapping his worm with that from my dec axis, which isn't quite true (as I've reported on here!). He believed that the ones he sent looked the same, but those returned were different. Perhaps I had done it by accident? (of course, accidentally stripped my only Eq6 and left the worms lying around).

I found this more than a little frustrating, especially as he had apparently re-built the mount (without the belt kit) found that it sounded like it was binding, and decided therefore that I must have sent him my dec worm (which is still in my mount and causing no problem at all in that axis). This was, by the way, on the night I took my best ever photo so far (Crescent Neb). Using my old, slightly wobbly dec worm...

I was really hoping he would do the conversion, rave about it and convince more people to do it. I even supplied better pulleys than those I had in my mount at the time. (I have since done new ones for mine, I'll admit).

I can still supply kits, but you must be confident with the work involved, and understand that there can be any number of very minor issues in a mount which can cause headaches. If you want a kit, they're £60 per axis, or £110 for both. If you want to supply your worms, please etch/engrave them with your initials maybe, or write it on them and put lacquer or (nail varnish) over it. I don't want to go through that scenario again.

If the guy concerned is reading this - please do the mod, and set it up as I've suggested here. It will be miles better - I promise.

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