TEST OF THE PRS-100 ROTATION STAGE

Spartan IR Camera for the SOAR Telescope

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We report a measurement of the tilt of the Phytron PRS-100 rotation stage when subjected to a torque. The hysterisis is small compared to the tilt. The response is 2.3 μrad/(N-m) at room temperature and 6.7 μrad/(N-m) at 77 K. For mirror insertion, the load is at most 1 N-m, and the tilt is less than 7 μrad, which corresponds to 0.4 pixel for both the f/21 collimating mirror the f/12 camera mirror. The Phytron PRS-100 rotation stage is acceptable for all mechanisms of the instrument.

1 Purpose

We plan to use Phytron PRS-110 cryogenic rotation stages for all motions. The tightest requirement is for inserting the f/21 collimating mirror or the f/12 camera mirror. There the stage must tilt by less than 17 μrad to maintain boresight alignment with the tip-tilt guider to one pixel. Used to turn the filter wheels or mask wheel, the requirement is much looser.

2 Test Jig

For the test, we built a test jig for measuring the tilt when a torque is applied. (See Figure 1.) To exert a torque on the rotation stage, a weight, hung on a string and pulley, pulls the top plate. The tilt is measured by measuring the distance between the ends of the sensing posts.

A 17-μrad tilt is challenging to measure mechanically: the end of the sensing post moves only 3 μ. We use a Starrett 711–T1 dial indicator, which senses the position of a ball. The dial indicator is clamped on one sensing post, and measures the distance to the other sensing post. The dial indicator has tics every 100 μin and can be read to 10 μin (0.25μ).

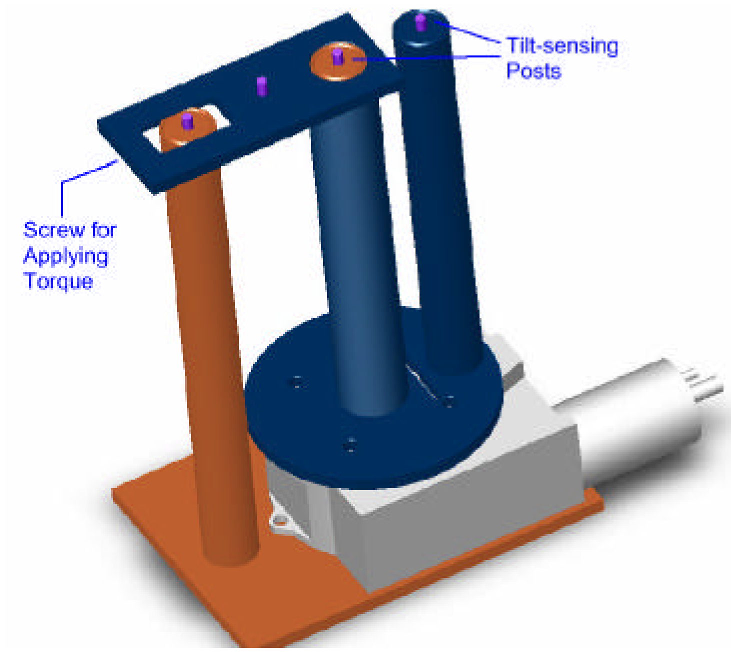

Figure 1 Jig for testing the rotation stage. The blue parts form a welded unit, and so do the red parts. A screw exerts a torque on the stage by forcing the long red post and the top plate together. That was replaced by a weight, attached to a string, which runs through a pulley. The tilt is sensed by measuring the distance between the tilt-sensing posts.

The original design had two problems. The base plate, on which the rotation stage and one sensing post are attached, bent when a torque was applied and caused the sensing post to tilt. We modified the base plate by adding two ribs. The second problem was the use of a screw to apply a torque. The screw causes a hysterisis. The reason for the hysterisis is unknown but may be related to the fact that the screw also exerts a lateral force. The system of a weight, string, and pulley replaces the screw.

The dial indicator or the contact between the indicator and measured part has a hysterisis of about 3 μ. We tapped the rotation stage to remove the hysterisis. Further tapping did not change the reading. (Tapping the rotation stage invariably settles the indicator too.) Then we touched the indicator, and the reading changed. Tapping made the reading change, and further tapping did not change it. Since the rotation stage had settled and we did not disturb it, the change in reading must be due to the indicator or its contact with the measured part.

To test whether the hysterisis is caused by the rotation stage or the measuring system, we measured posts that are not connected to the rotation stage and found the same hysterisis. We applied a torque to the leftmost post in Figure 1 and measured the distance between it and the middle post. The result without the rotation stage (Figure 2) is very similar to that with it (Figure 3). (The maximum torque was chosen to keep the deflection the same in the two cases, and it is smaller here because the connection between the leftmost post and base plate is weak.) The amount of hysterisis and the shape of the curve are similar for both cases, and gentle tapping eliminates the hysterisis. Thus we conclude that the hysterisis is not caused by the rotation stage.

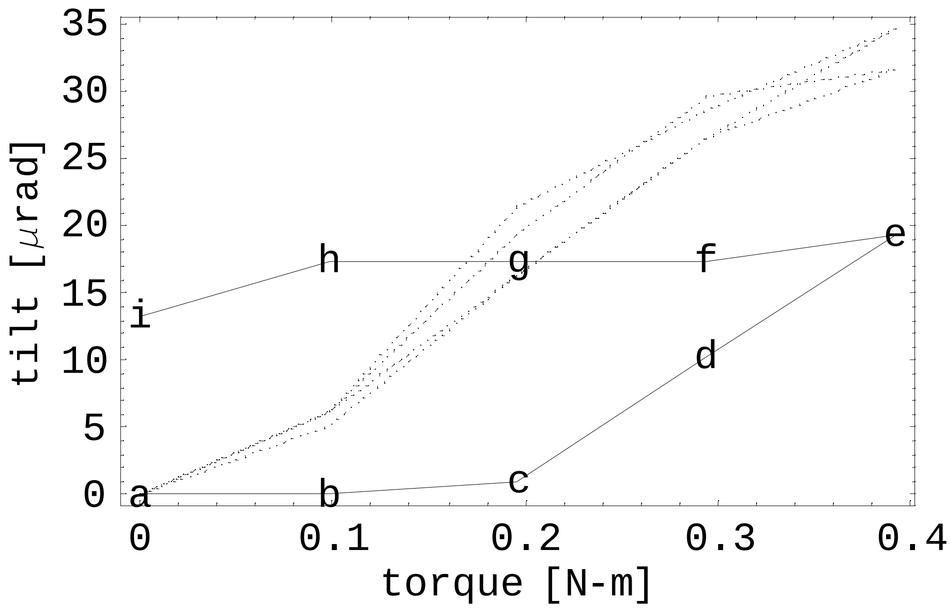

Figure 2 Tilt of a post that is not connected to the rotation stage. For points a–i, the torque was changed gently; for the other points, the top plate was tapped gently after changing the torque.

3 Results

We measured the response of the stage at room temperature and at 77 K.

The hysterisis is evident for points 0–8 in the top panel of Figure 2, where we applied or removed weights smoothly without causing vibration. (The hysterisis of 23 μrad amounts to a displacement of the end of the sensing post of 5 μ.) For the other points, we tapped the top plate gently, and little hysterisis is seen.

The method of applying torque also applies a force, and the measurement of the end of the sensing post is due to a displacement of the whole sensing post as well as a tilt. We measured the displacement at room temperature to be 0.5–1 μ for a 40-N force. Therefore the tilt is 7–13% less than the measurement of the end of the post indicates. We adopt a correction of 10% for both room temperature and 77 K, even though the measurement was made only at room temperature.

The slope of the data gives an inverse spring constant of 2.3 μrad/(N-m) at room temperature and 6.7 μrad/(N-m) at 77 K with a 10% correction for displacement of the sensing post.

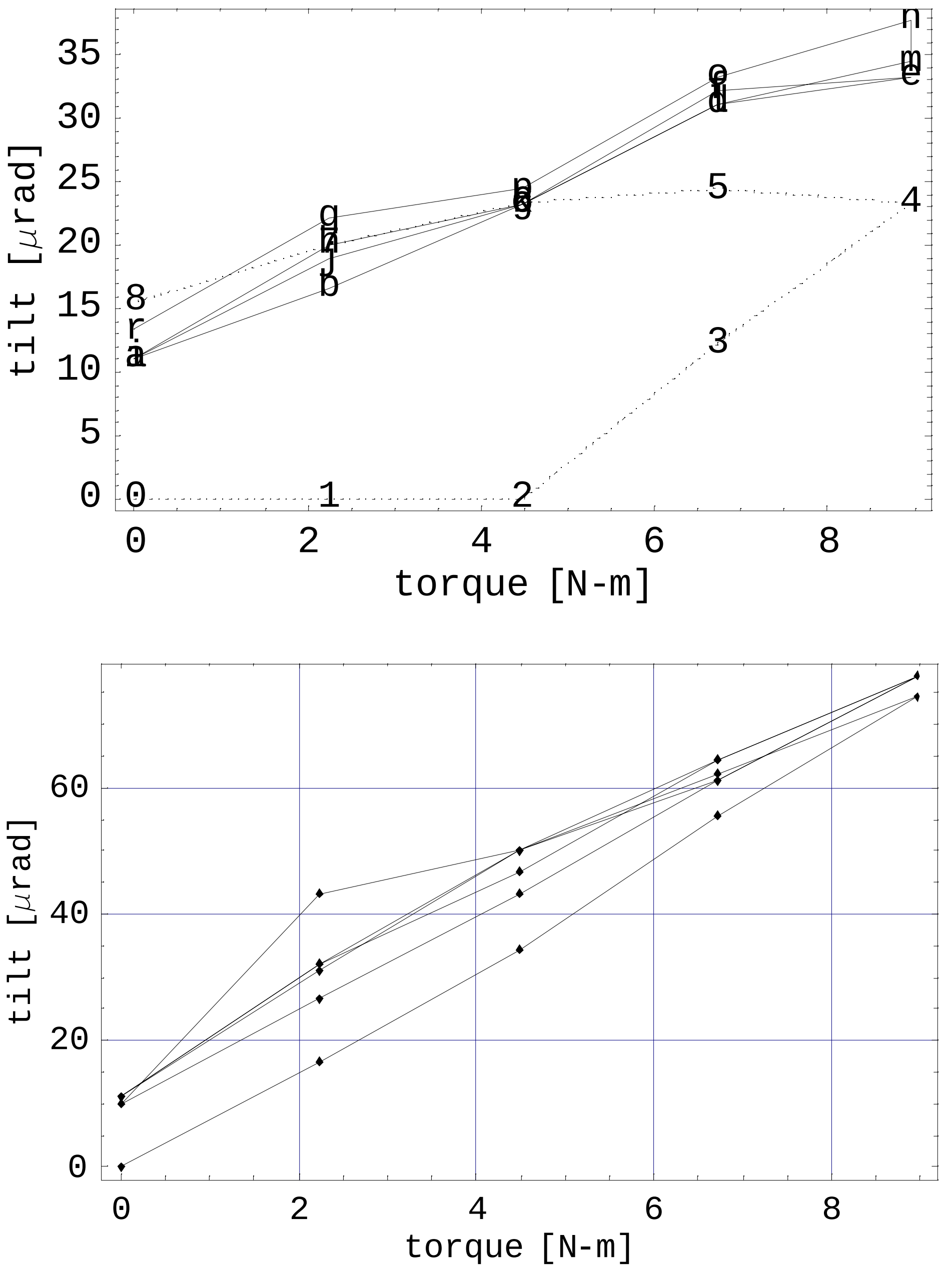

Figure 3 Tilt vs torque at room temperature (upper panel) and at 77 K (lower panel) For points 0–8, the torque was changed gently. For the other points, the top plate was tapped to remove hysterisis. The zero point for tilt is arbitrary.

4 Conclusion

The PRS-110 rotation stage is acceptable for all mechanisms, as the following discussion shows. The key finding is that the hysterisis of the rotation stage is much smaller than the response to torque.

4.1 Mirror Insertion

The torque of the mirrors is at most 2.6 N-m. The mirror and support was designed and analyzed for a ϕ180-mm mirror (O Loh, 2003, “Design of the . (The diameters of the f/21 collimator and f/12 camera mirrors are 175 mm and 162 mm.) The total load is 4.9 kg, and the center of mass is 31 mm from the surface that mounts to the rotation stage. The center of the bearings is about 27 mm from the surface.

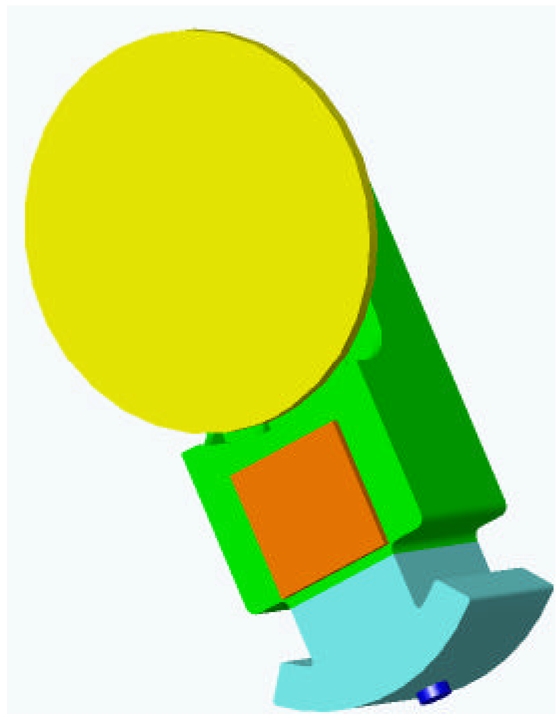

Figure 4 Mirror assembly, which consists of the mirror (yellow), support (green), counterweight (blue), and attachment (orange) to the rotation stage. Figure is taken from O Loh, ibid.

It is easy to reduce the torque to zero by moving the counterweight (the blue part in Figure 3) to the other side of the rotation stage.

Suppose the load is 1 N-m. Then the tilt is 7 μrad over a 360° rotation of the instrument, which corresponds to 0.6 pixel for the f/21 collimating mirror and 0.3 pixel for the f/12 camera mirror.

Since the hysterisis is much smaller than a pixel, a shift of less than a pixel can be removed by the look-up table in the tip-tilt guider.

4.2 Other Mechanisms

The requirements for the other mechanisms are much looser. The detector rotator may tilt by 250μrad and still keep focus across the detector. The requirement for the mask wheel is similar. The tilt of the filter wheels is very loose.