Repair of the ESA-Haystack Radiotelescope

Joachim Köppen

Observatoire de Strasbourg

Jan. & June 2013

Previous problems

In autumn 2010 it occurred that the telescope had problems with the elevation drive. Error messages such as “Lost counts, motor stalled when going UP in elevation” were encountered. Also, in some of the data a shift in elevation was noticed. Eventually the telescope could not be moved in elevation. After removal, inspection of the linear actuator showed that it was completely stuck, while no part seemed to be broken, and everything appeared OK with the motor and the gear. With liberal application of penetrating oil and judicious application of manual force, the inner tube of the actuator was made to rotate again. Systematic and extensive trials of extending and contracting the actuator by its own motor lead again to a smooth operation.

While the manufacturer claims that the actuator is maintenance-free and thus needs no lubrication, it appears that the origin of the problems is that rainwater can easily enter the interior of the actuator via the small gap at the top near the swivel stud (shown in Fig.1).

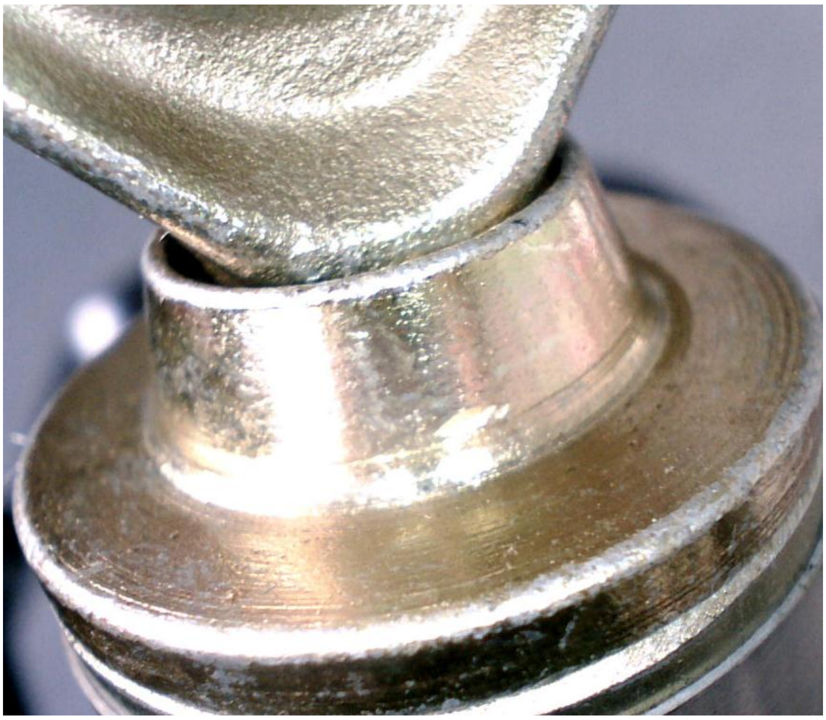


Fig.1 *The swivel stud at the top of the linear actuator is surrounded by a gap through which rainwater may enter the inner workings of the device.*

This also led to the washing down of the lubricant, which was apparent as black residue deposited at the bottom end, near the motor housing. Fig.2 shows the situation in 2013

Fig.2 *At the bottom end of the linear actuator tube a substantial amount of black residue was found in Jan.13, which appears to be mixture of the original lubricant, the applied oil, and perhaps metal rubbings.*

In the following years, some oil was regularly applied to the top of the actuator tube. Although this continued to wash out more of the lubricant, it has resulted in a faultless operation of the telescope.

New problems

During summer 2012 problems were encountered with the azimuth drive, which gave error messages when “moving CW in azimuth”, usually when moving from stow position towards the intended observational position. Initially this occurred rarely. Grease, oil, and lithium lubricant were applied to various positions of the azimuth axle, and eventually also to the chain between electric motor and the worm gear. These measures gave some relief, but no complete removal of the problems could be achieved.

Finally, in November 2012, the telescope stopped entirely functioning in elevation. It remained stuck at some angle, but strangely with any error message. Hence, the electric motor never encountered resistance, and the turns counter delivered the correct number of counts.

The elevation linear actuator (“pushrod”)

In January 2013, the linear actuator was removed from the telescope. Detailed inspection showed that the electric motor and the gear train worked completely normal. Also, the inner tube of the actuator could be moved without resistance by rotating the inner threaded rod. Eventually it became apparent that the coupling ring between motor axle and threaded rod no longer provided any coupling, because its two teeth did no longer engage in the appropriate slots of the threaded rod. The rather small teeth showed heavy wear.

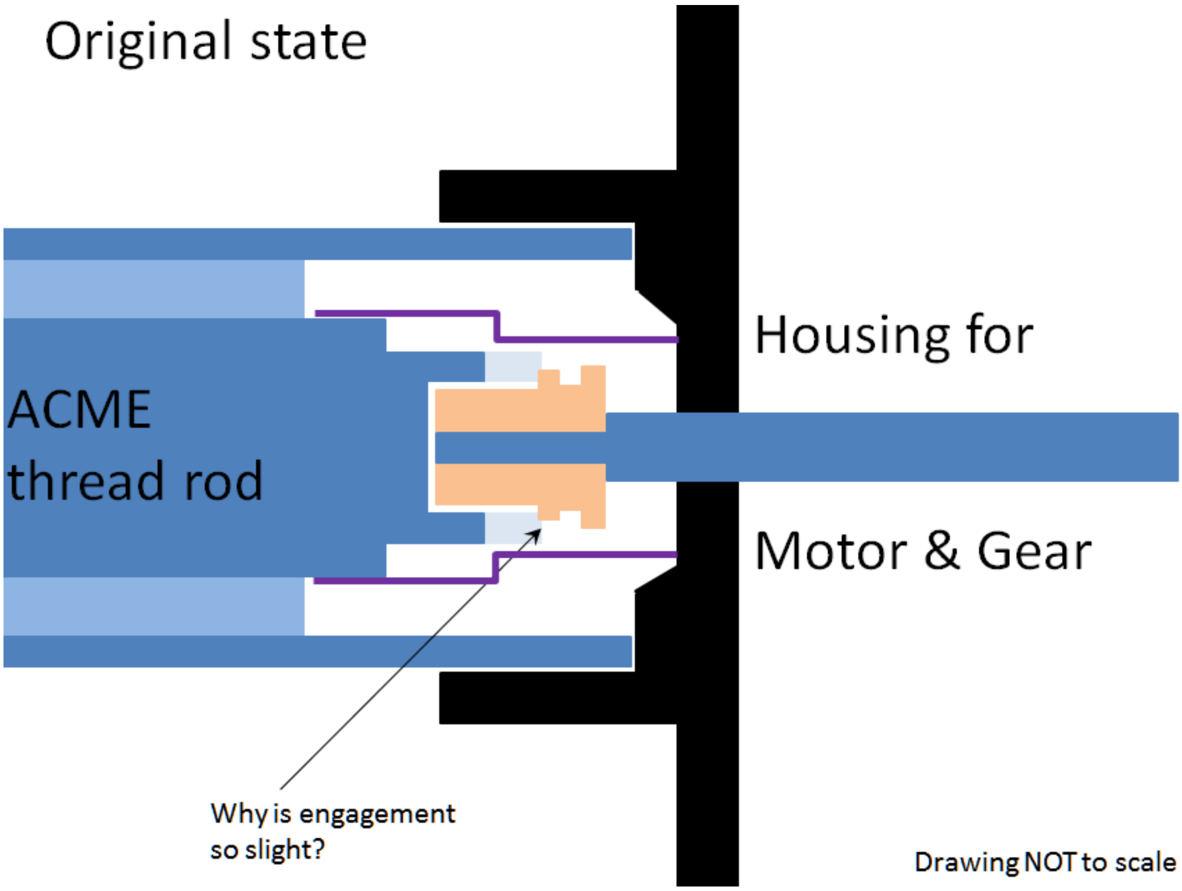


Fig.3 *Details of the coupling of the doubly flattened motor shaft to the linear actuator threaded rod. The brown part is the aluminium coupling ring, whose teeth engage slightly in the slots in the walls (light blue) of the threaded rod. The violet part is the plastic tubular cover.*

During the careful inspection to unravel and understand the inner workings (Fig. 3) of the linear actuator it was also realized that the teeth of the coupling ring never went very deeply into the slots, although the latter are rather deep (about 5 mm). It may be estimated that the teeth had only a fraction of a millimetre of contact with the slots. This appears a rather strange design!

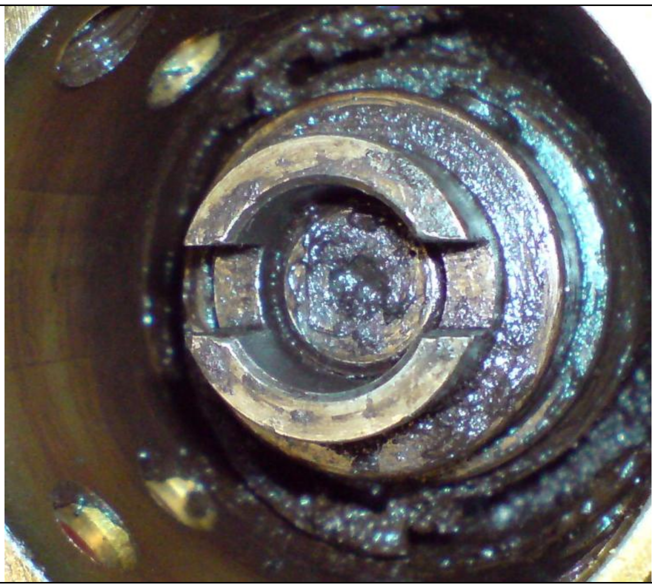



Fig.4 *In the original state the coupling ring's teeth engage with the slots of the threaded rod only lightly (left).* **Fig.5** *The slots are much deeper than the teeth can reach (right).*

The absence of engagement of the coupling ring and the threaded rod thus is the reason for the non-functioning of the elevation drive, while the rotation counter – which counts the rotations of the motor axle but not those of the threaded rod itself – would not reveal any fault or error message. The heavy wear on the teeth (Fig.9) is witness that this kind of slipping had already occurred earlier and is responsible for slips in elevation noted in some data.



Fig.6 *The coupling ring (original state) viewed from the side (left) and the top (centre* **Fig.8***). The lower part of a tooth shows heavy wear, while the top side is untouched (right* **Fig.9***).*

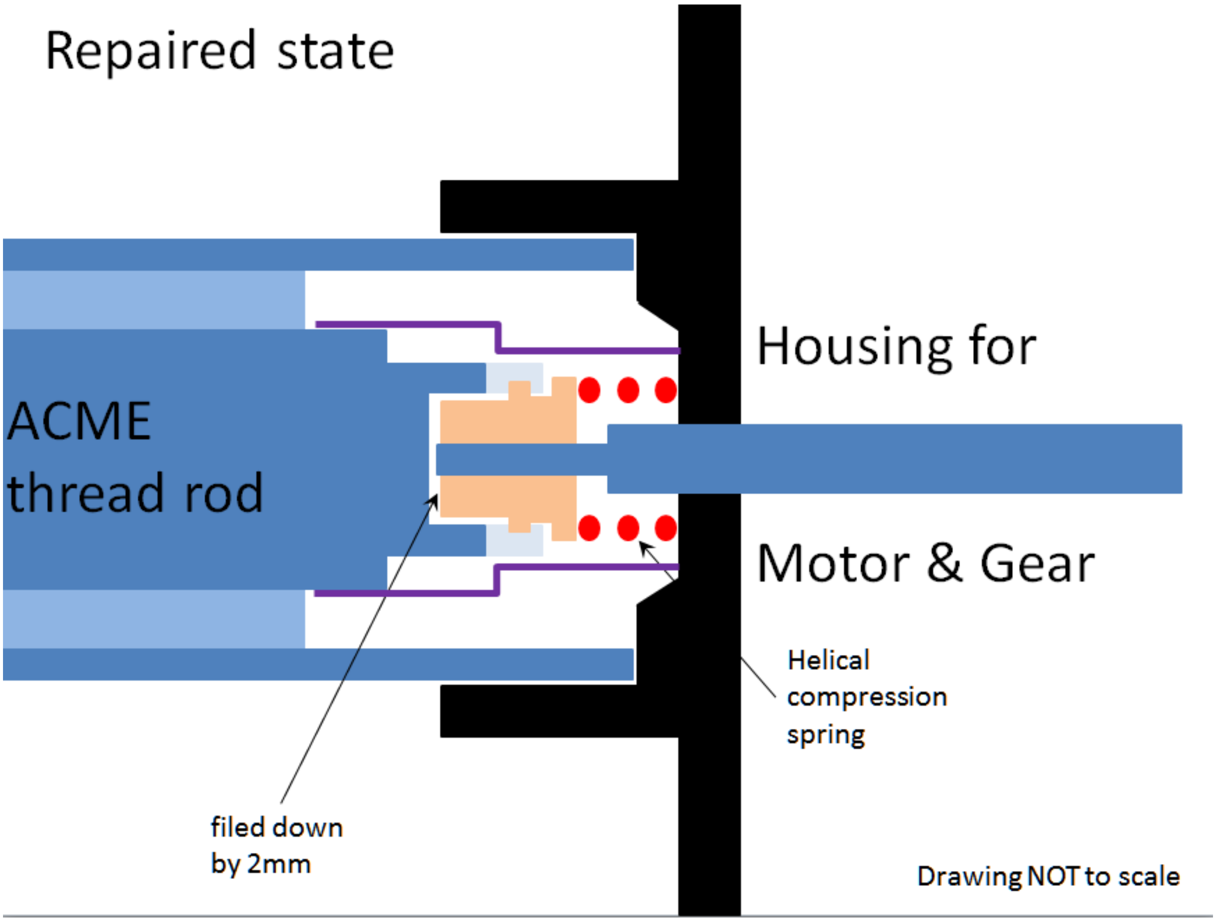


Fig.10 *The coupling of the motor and threaded rod, after modification.*

As the coupling ring's bottom would sit flush in the opening of the threaded rod, which places the teeth too high to engage with the slots, it was decided to file away about 2 mm from the bottom end. The altered situation is shown in Figs.10 and 11. The deeper sitting teeth guarantee full coupling of motor and threaded rod.

Fig.11 *The reduced coupling ring now engages fully with the threaded rod's slots.*

Since in the original arrangement the coupling ring is held in position by the flattened part of the motor shaft (Fig.12), in its shortened form it needs to be pushed towards the threaded rod's receptacle. This is done by a compression spring of suitable dimension, made from a large paperclip. The spring need not be under tension, as it is sufficient to hold the coupling ring at proper position but without rubbing into e.g. the plastic wall of the motor housing due to the shaft rotation.

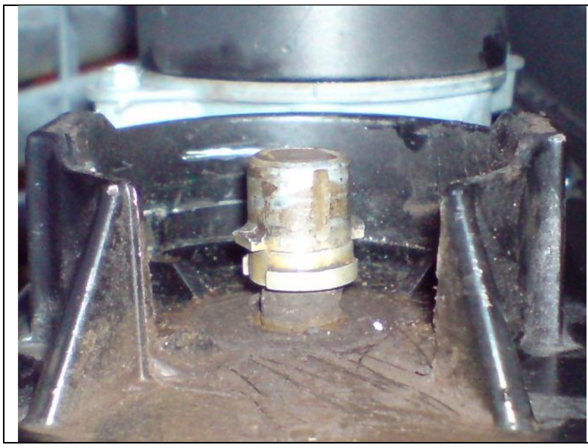
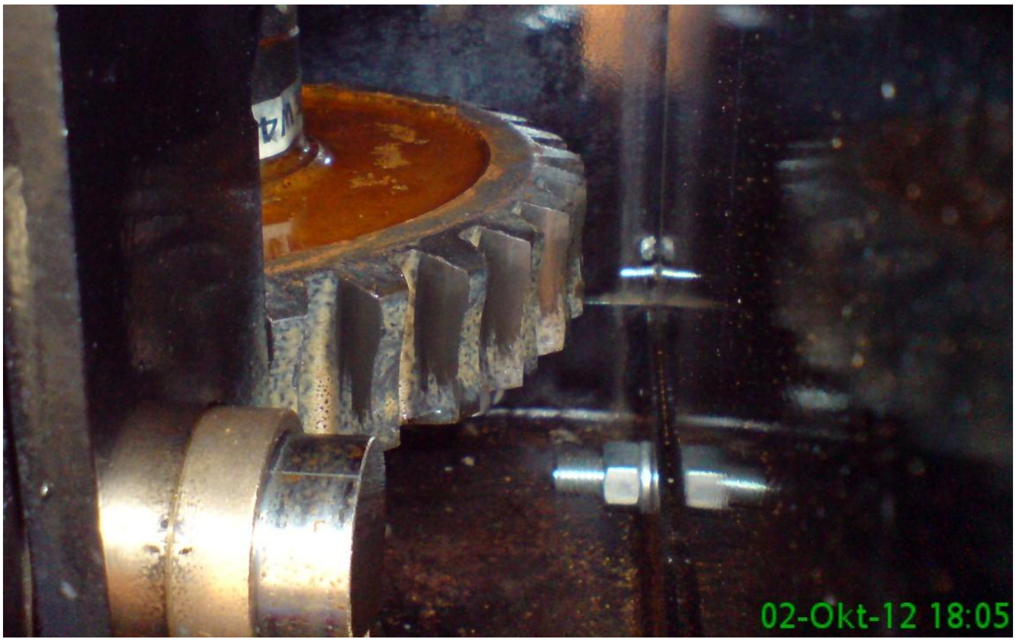


Fig.12 *View of motor housing with the receptacle for the actuator rod, and the motor shaft (with the coupling ring in original state: left).* **Fig.13** *(right) the motor shaft is flattened on two sides to receive the coupling ring and hold it at proper height.*

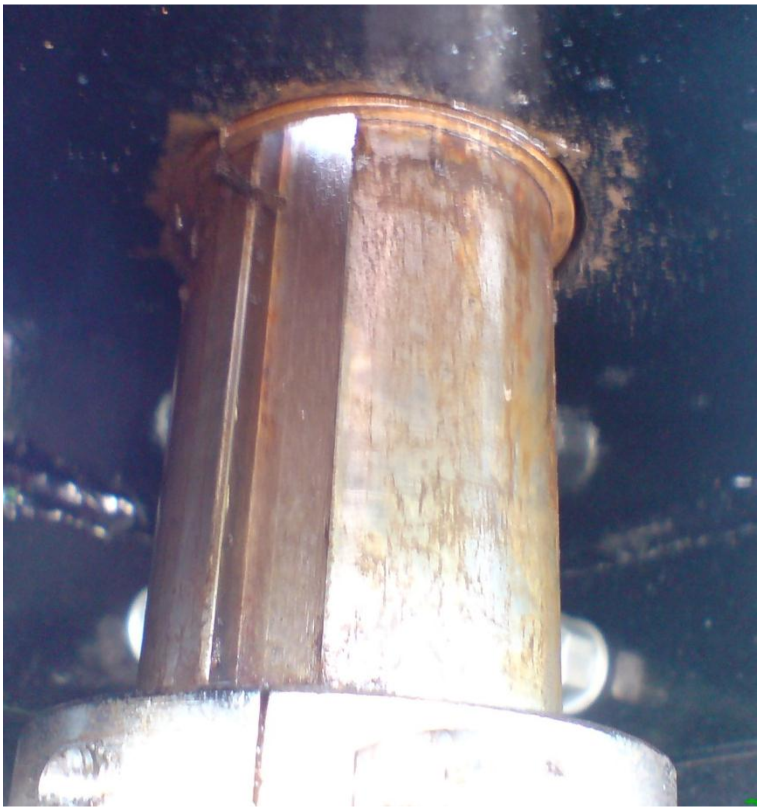
Fig.14 *The reduced coupling ring is held up by a small compression spring.*

The Azimuth Drive

One of most striking things that appear when one opens the motor box is often the presence of plenty of water which fills the upper side of the big azimuth gear wheel:



This is rainwater that seeped into the box through the vertical shaft's bushing at the top of the box, but mainly via a hole just below the bar that constitutes the elevation axis created by the large groove which runs all along the vertical shaft, and which was not fully closed by the welding to the horizontal bar. This view was taken when the outer collar of the bushing had been removed:



To prevent further seeping, I pushed some plastic bag material into this hole:

Of course this was not the reason why the telescope has started in spring 2012 to have difficulties to be moved in azimuth: Frequently the motor simply stalled, giving the message "lost counts, motor stalled when going CW in azimuth". Application of white lithium lubricant to the worm and the gear wheel as well as use of penetrating oil at various spots, like the chain and all bearings helped for some time, but finally in winter 2012/13 the azimuth drive was completely stuck.

The longish winter rendered it impractical to try to dismount the antenna dish and to give the motor box a thorough inspection. This could only be done in April 2013. Although the weight of the antenna was removed, the azimuth drive continued to stall immediately. The motor box was partially disassembled, so that all parts of the gear train could be inspected and the mechanical workings could be carefully studied and fully understood. The initial suspicion that corrosion (from e.g. the seeped rain water) might have caused a blocking or an increase of the friction of some part was explored, but none of the obvious critical locations appeared to be in fault. Manual rotation of the gear wheels did not reveal any stronger resistance than one would have anticipated. Tests showed that the electric motor would work perfectly on its own, but that it would stall when connected to the gear via the chain. Application of lubricants and relocating slightly the electric motor brought only a temporary improvement.

In June 2013 I removed the old grease from the chain and its large wheel, bathed it in WD40. Dirt was removed from other parts, including those which would not affect the movements. It was also noticed that there is some play in the vertical shaft in its upper bearing, and that the movement of the gears might become easier, if one pushed sideways the vertical shaft by handling the elevation bar. However, this did not appear to be systematic, e.g. when the vertical shaft was pushed in a certain direction. A first reassembly did not result in a change of the situation. The electric motor was fully removed and tested with a DC power supply to give fully satisfactory operation. Some more application of WD40 to various spots followed. Reassembly then showed flawless operation. The telescope could be moved to various azimuths in either direction…

Summary

The repair of the pushrod resulted in a definitive identification and removal of the fault, which must be suspected to be a manufacturing or design fault. The entry of rainwater by the small openings at the top of the rod would still give some problems, but these holes can also be used to put in oil. If this is done in a regular fashion, it seems likely that further problems with lubrication can be avoided. The only disadvantage will be that oil and dirt will come out at the lower end and drop to the ground. Regular inspection of the lower end would be advisable.

The azimuth drive seems to suffer from friction that had increased over the years of operation. All parts are otherwise in good working order. While the exact origin of such friction could not be located, lubrication of all relevant parts might be a means to keep it operational. Most probably the main source of friction in the drive was the old grease in the chain and the teeth of the large wheel. It would seem to be rather sensible to closely monitor the operation of the entire mechanics, as this could well constitute a long-term problem with this instrument whose design might not have been executed with the weather conditions in central Europe in mind.