Better Dobsonian Bearings

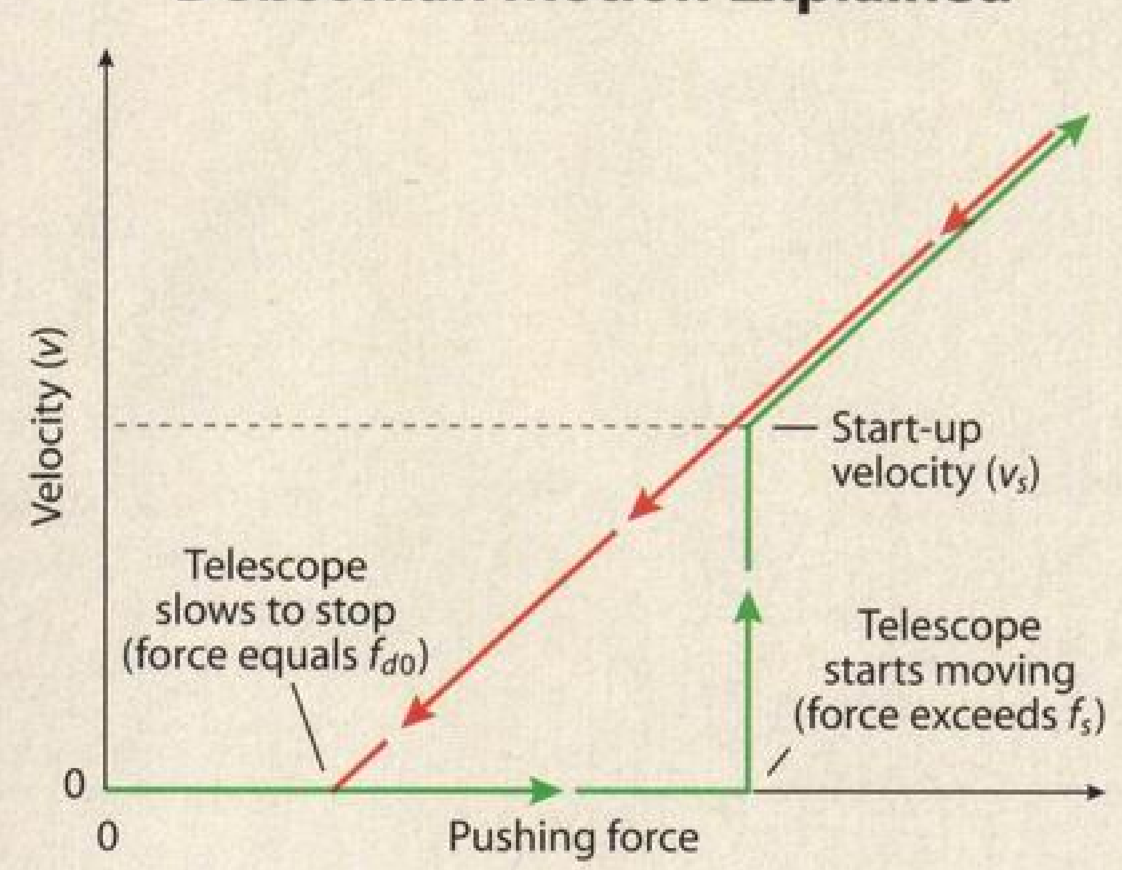
Is the well-known magic combination of Teflon and Ebony Star really the best for scanning the skies? | **By Martin Lewis**

NEWTONIAN REFLECTOR TELEscopes on Dobsonian mounts enjoy enormous popularity mainly because they are simple to use and inexpensive to build or buy. The best examples combine smooth, controllable movement with rock-solid stability. Too often, though, poorly chosen bearing materials lead to telescopes with less than satisfactory motions, and the result is a frustrating observing session with more time spent trying to center objects in the eyepiece than actually looking at them.

In the October 1999 issue of *Sky & Telescope* (page 128) I described a novel material for Dobsonian bearings that offered improved performance over the standard choice of pads made of Teflon (DuPont's trade name for polytetrafluoroethylene plastic). This alternative material, called Teflon Sheet, exhibited frictional properties that made it a superior choice. However, some readers were concerned about the thin plastic coating wearing through to the fiberglass weave underneath. Since that article appeared, I have continued investigating Dobsonian friction and testing materials, attempting to find an even better bearing material that isn't prone to wear-through.

The author is seen here with "Fossil Light," his 18-inch truss-tube Dobsonian reflector. The telescope not only gives satisfying views of the night sky but also functions as a final real-world test bed for new bearing materials. All photographs courtesy the author.

Dobsonian Motion Explained



How exactly does a Dobsonian move? Imagine a stationary telescope. As a pushing force is applied to the telescope, you move right along the x-axis, but the telescope speed remains zero until the pushing force overcomes the static frictional force (f_s) and you jump straight upward from the x-axis to the diagonal line. The speed that the telescope will be moving at that point is the start-up velocity, (v_s). If the pushing force is increased, you move up the diagonal to higher speeds. If the pushing force is decreased, the telescope's speed drops, and eventually the telescope will stop moving (f_{d0}).

A Matter of Motion

Three characteristics determine how well a Dobsonian telescope moves:

- The amount of force required to move the telescope
- How controllable the movement is at slow speeds
- The start-up speed — the initial velocity of the telescope when the minimum force to just get it moving is applied.

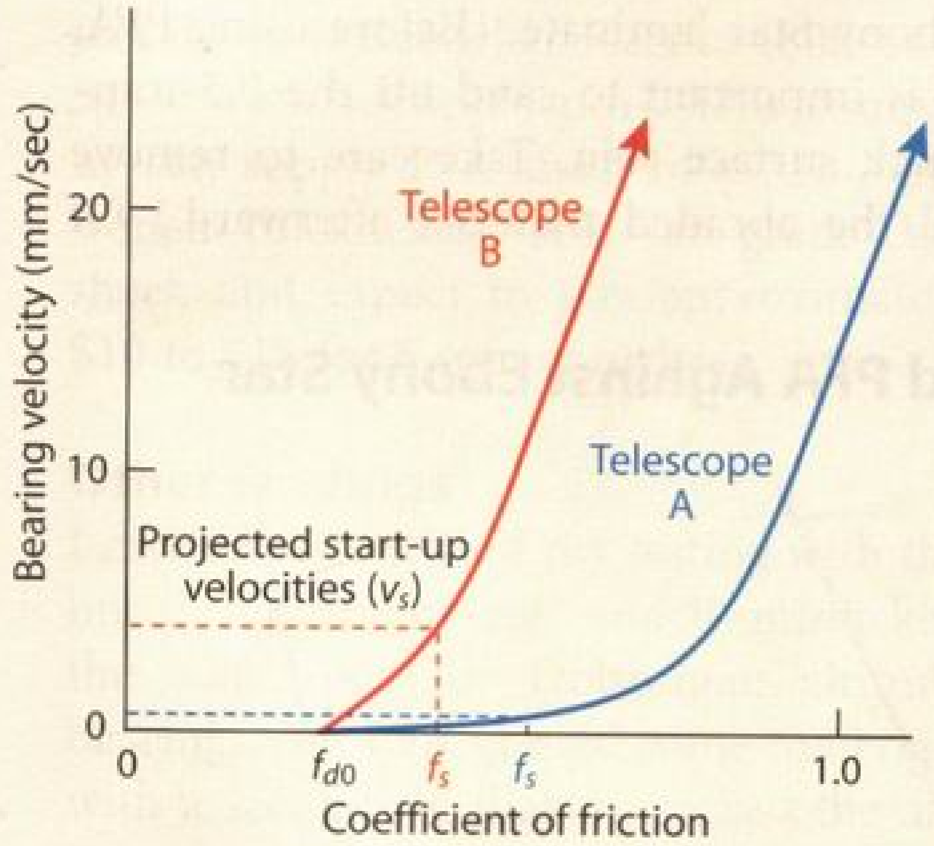
Each of these is important; however, undue attention is often paid to the first of these at the expense of the other two. Many observers wrongly assume that a scope that moves easily will also be easy to control. This is not necessarily the case.

The above characteristics are intimately related to two key frictional parameters: the coefficient of static friction (f_s) and the coefficient of dynamic or kinetic friction (f_d). The first is proportional to the amount of force required to just get the bearing surfaces moving relative to one another. The value for f_s increases the longer the telescope has been stationary — for my measurements I chose wait times of 5 seconds and 2 minutes, representing the extremes for viewing objects at high and low magnifications. The second coefficient, f_d, is a measure of the amount of force required to keep the telescope in motion. This is not constant but varies significantly with velocity, and its value when the scope is on the verge of stopping is denoted by f_{d0}. This is illustrated in the diagram on page 122.

The difference between f_s and f_{d0} is often called "stiction." It is a common misconception that it is *only* this difference that determines how easily the telescope can move small controlled amounts from stationary. What is more important is the start-up speed, which must be low to avoid overshooting the eyepiece target. Although this does depend on the amount of stiction, it also depends on how f_d changes with velocity.

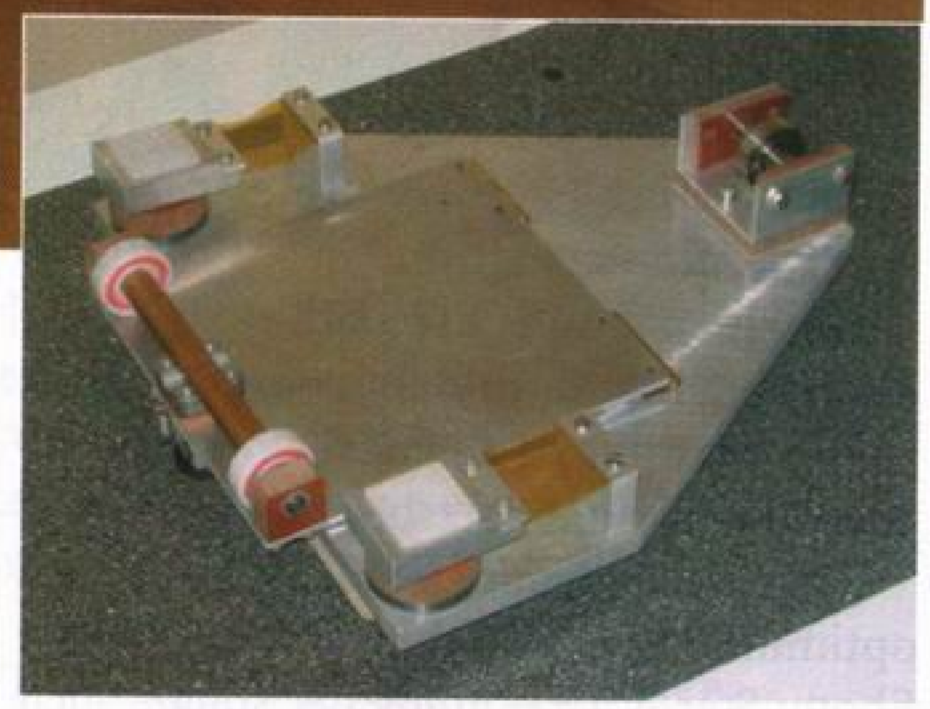
To illustrate this, consider the two telescopes shown in the graph at left. Note that while Telescope A requires more force to get it moving (it has a higher value for f_s), the first part of the curve is shallow, which means that its start-up velocity will be low, and it will be easy to move the telescope in small, controllable amounts. Telescope B has a much steeper curve, and, though less force is needed to start the scope moving, the start-up velocity is much higher, and the telescope's motions will be much harder to control.

Idealized Telescopes



These curves show the movement of two fictitious telescopes. The shallower the curve, the more easily controlled the movement. In this example, Telescope A would be easier to move in small increments even though it actually requires more force than Telescope B to start moving.

The author used this test setup to measure the frictional properties of various bearing materials in a controlled situation. The material being tested is mounted to the underside of a weighted sled, which slides on a tabletop covered with Ebony Star laminate, simulating a Dobsonian telescope's altitude motion.



This view shows the underside of the test sled. The two white squares are test pads of perfluoroalkoxy fluorocarbon, or PFA.

Tester Design

Armed with the insights described above, I knew that properly assessing the suitability of any combination of bearing materials meant I would have to determine f_s and also the way in which f_d changes with velocity. The test rig I built, pictured above, is designed to mimic a Dobsonian telescope's altitude motion. At its heart is a weighted test sled with a wheel at the front and two self-leveling blocks at the rear. The pads of bearing material being tested are attached to these blocks with double-sided tape. The sled, weighted with a specific load, is dragged over a flat sheet of the complementary base material by a flexible wire. This wire runs over a pulley attached to a digital encoder, calibrated to read the sled velocity. The resulting data allow f_d to be plotted against linear velocity and the value of f_s to be determined.

I took many steps to achieve consistent and meaningful test results. For example, I always made sure that the test surfaces were scrupulously clean and that the pads were prepared in such a way to ensure uniform contact pressure between test surfaces.

Test Results

Teflon and Ebony Star laminate. Pure "virgin" Teflon and Wilsonart Ebony Star laminate are regarded by most telescope makers as the gold standard against which all other bearing combinations are judged. These materials have been used in countless home-built and commercial Dobsonian scopes over the years, mainly due to the overall low values of f_s and f_{d0}, which allow telescopes to move easily.

My experiments found a low f_{d0}, around the 0.06 mark. However, as shown in the graph below, the shape of the curve is far from ideal — it starts off steep and stays that way as the velocity of movement increases. The derived values for f_s for this pair of materials correspond to a start-up velocity of 5 millimeters per second for a stationary period of 5 seconds. For a 2-minute wait this increases to 11 mm per second, indicating that in this situation the scope would be difficult to move in small increments without overshooting the target.

The generally accepted value of the optimum pressure for Teflon against Ebony Star is 15 pounds per square inch (psi). My experiments showed, however, that for slewing speeds of 15 mm per second or less, the curves are fairly similar for pressures in the range of 15 to 50 psi. It is only when the pressure drops below 10 psi that the low-speed curve steepens and f_d increases, giving inferior performance. Above 15 mm per second, higher pressures lead to frictional heating of the pads, which reduces the coefficient of friction.

I also tested the performance of this bearing combination across a temperature range of 8° to 24.5°C (46° to 76°F). Although the shape of the curves didn't change, f_{d0} decreased more than 50 percent as the temperature went up.

Teflon and aluminum. Another popular combination is Teflon pads bearing against aluminum. The results are also shown below. What is immediately evident is that, though the coefficient of friction is nearly double that for Teflon and Ebony Star, the curve is much closer to the ideal. Bench testing of this combination gave projected start-up speeds of 0.2 mm per second after a 5-second wait and 5 mm per second for a 2-minute wait.

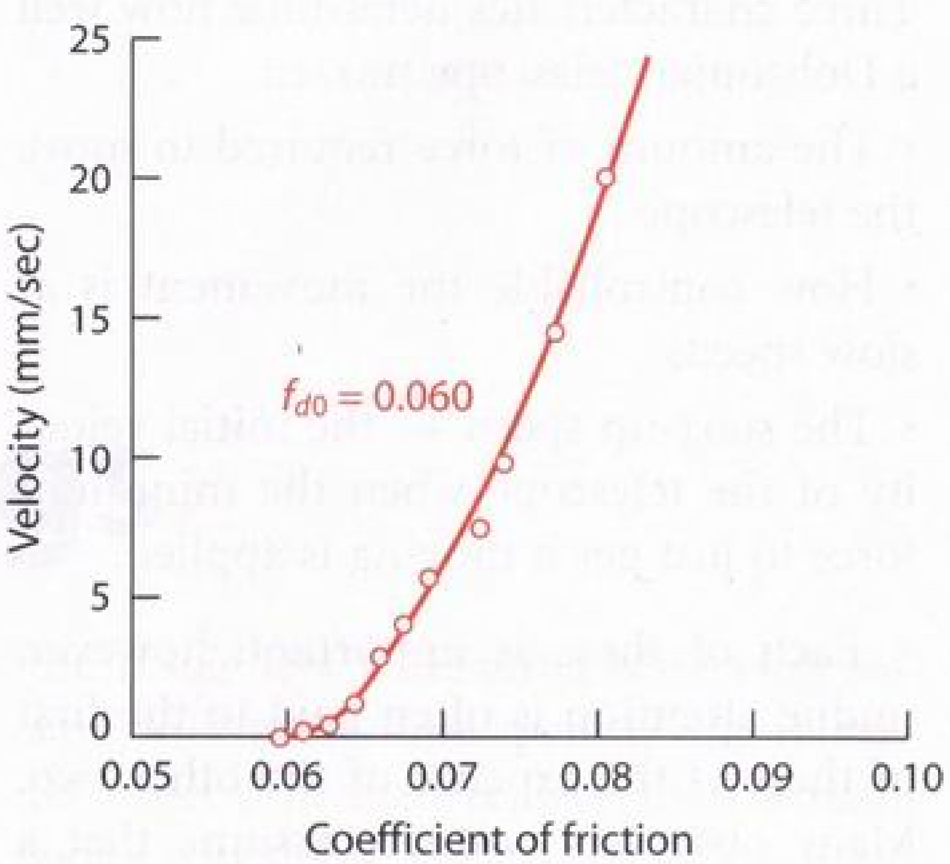
So which bearing material is best? According to my tests, the answer is "none of the above."

These results are significantly better than those for Teflon against Ebony Star, but the aluminum bearings produced black flakes that are a mixture of Teflon and metal oxide. My guess is that these are likely to have a detrimental effect if allowed to badly clog the bearing surfaces.

Teflon and polypropylene. The first Dobsonian I owned had altitude bearings consisting of Teflon pads rubbing against two 8-inch-diameter rings of thick-walled polypropylene pipe. As the plot shows, the resulting value for f_{d0} is surprisingly similar to the Teflon/Ebony Star combination. The curve starts off very shallow, showing lots of promise, but then the gradient abruptly worsens. Start-up velocities are too small to detect after a wait of 5 seconds but rise to 5 mm per second after a 2-minute wait — similar to aluminum against Teflon.

UHMW and Ebony Star laminate. Another popular pad material, often found on budget Dobsonians, is ultrahigh-molecular-weight polythene (UHMW). As shown above, UHMW's f_{d0} was similar to Teflon's, but, though the curve shows a nice shape, the gradient is really too steep. The f_s values after 5-second and 2-minute waits produced start-up speeds of 0.4 mm per second and 12 mm per second, respectively. This is a better start-up velocity than for Teflon against Ebony Star for short waits, but similar for waits of a few minutes.

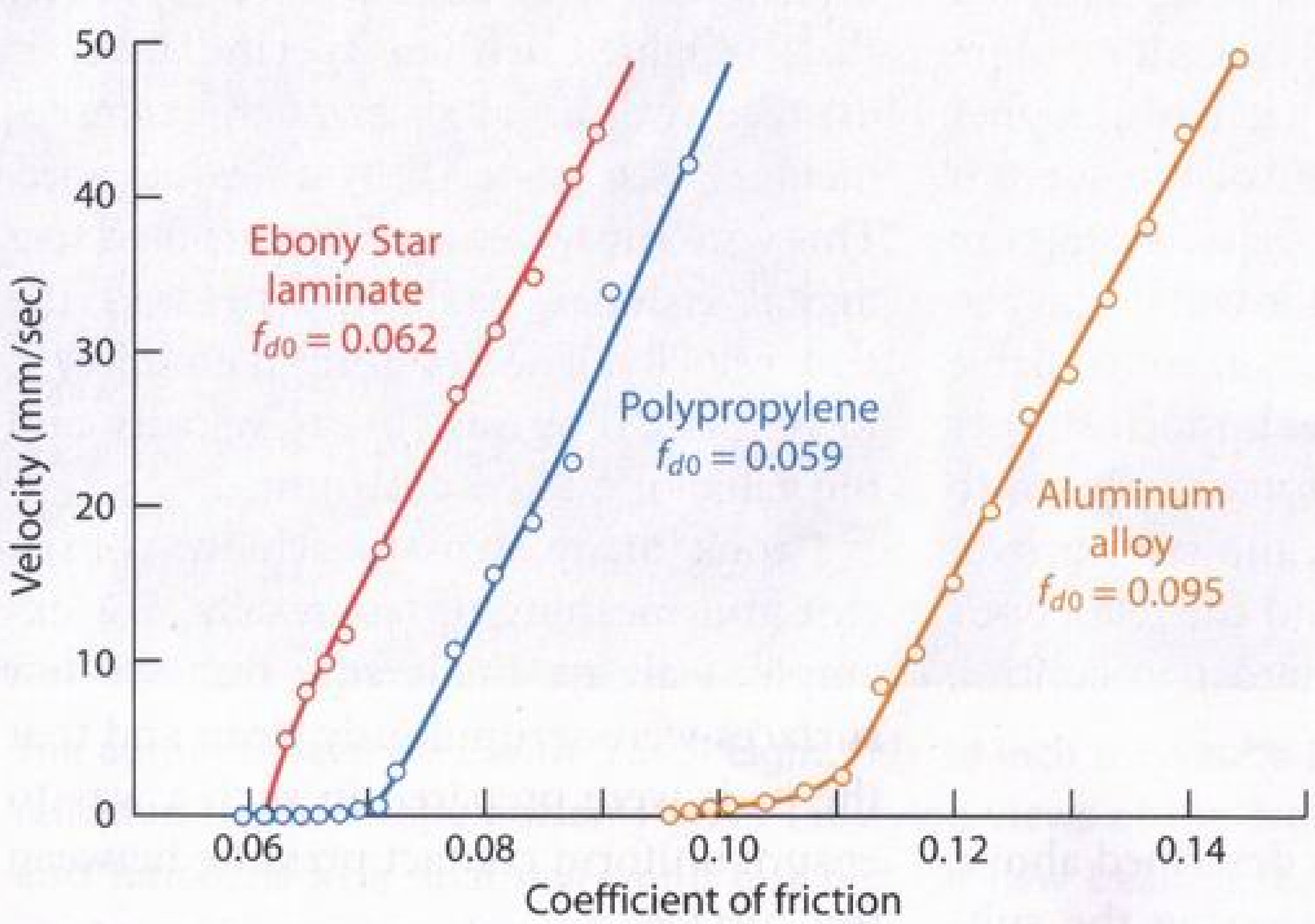
UHMW Against Ebony Star



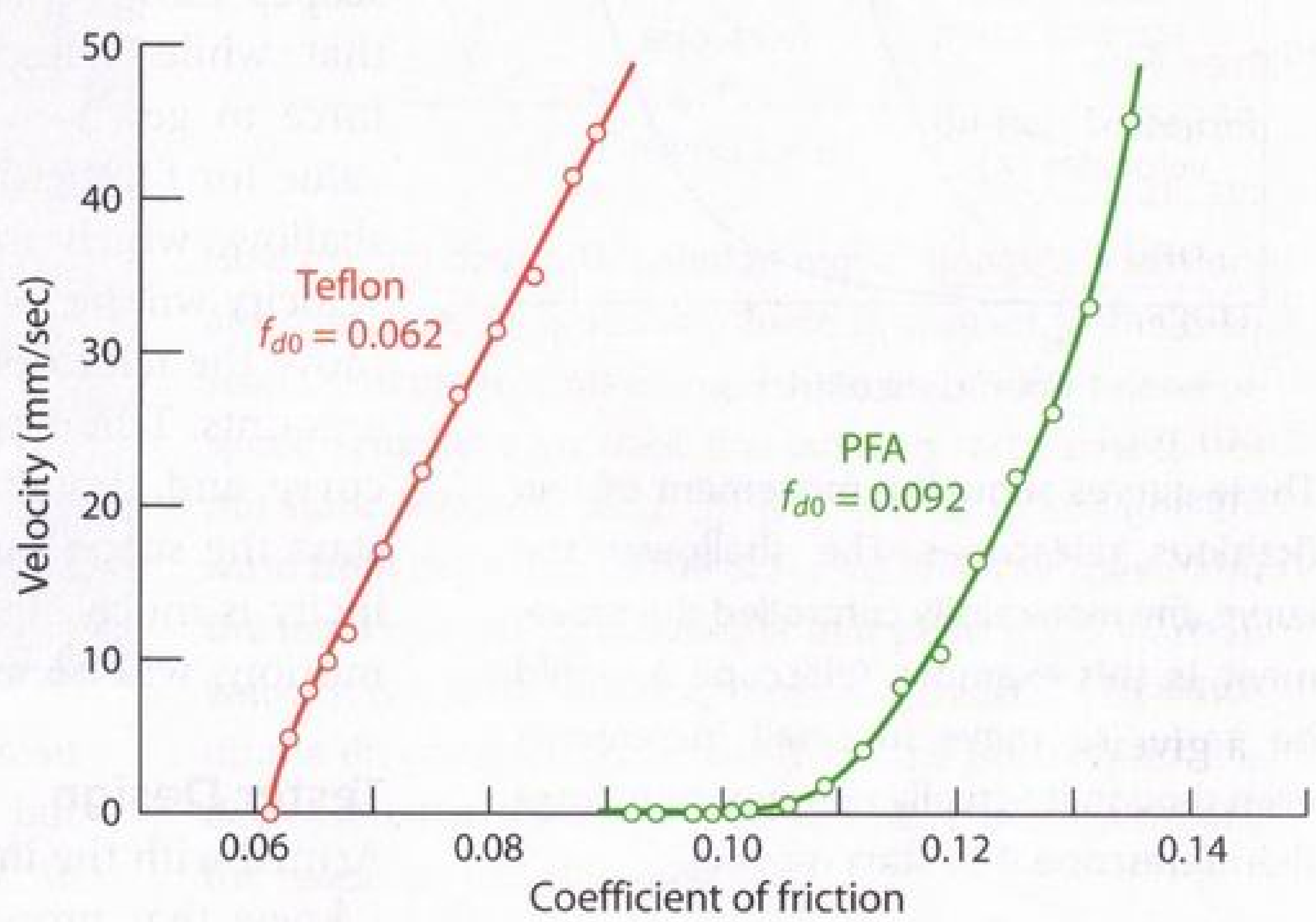
A New Find

So which bearing material is best? According to my tests, the answer is "none of the above." I obtained the best results by using a completely new pad material — perfluoroalkoxy fluorocarbon, or PFA. It is a relative of Teflon but has greater mechanical strength. I tested clean ⅛-inch-thick pads of this colorless, translucent material in contact with Ebony Star laminate. (Before using PFA, it is important to sand off the 0.5-mm-thick surface skin. Take care to remove all the abraded material afterward.) Of

Teflon Against Various Materials



Teflon and PFA Against Ebony Star



all the combinations of materials I measured, this came closest to matching the ideal curve. As plotted at lower right (facing page), the PFA curve has a lovely shape. Even after a stationary period of 2 minutes, the PFA pads gave a start-up velocity of less than 0.02 mm per second. This performance is not only better than Teflon, it is even better than the Teflon Sheet material that scored highest in my original tests. In addition, PFA is more durable than Teflon Sheet because it is a solid block rather than a thin coating.

The only caveat with PFA is that its f_s is some 50 percent higher than that of Teflon. This simply means that a Dobsonian telescope using PFA bearings would have to be pushed with more force to get it moving. This may be a problem for some large and heavy scopes, but it is likely to be a significant advantage for smaller scopes, which generally move too easily.

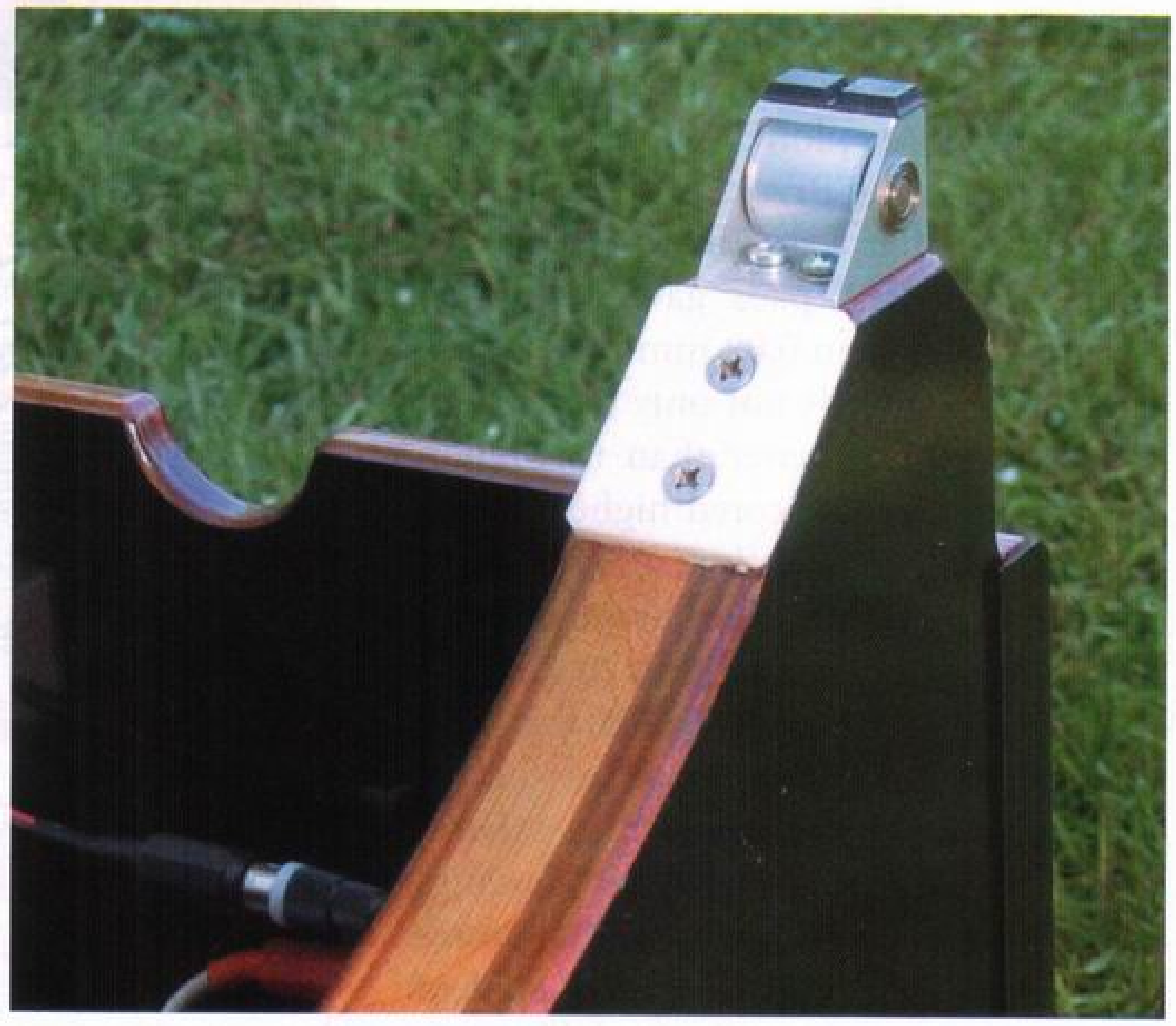
The behavior of PFA bearing against Ebony Star was also measured over a range of loads and temperatures. Pressures below about 10 pounds per square inch gave inconsistent results and a steeper start-up curve. The curves for 16.6 psi up to 57 psi were similar, the only difference being an increased wear rate at the highest pressures. There was little change noted for tests over a temperature range of 4.5° to 24°C (40° to 75°F), but at 24°C the f_d decreased slightly.

PFA is a specialty plastic, and it may be difficult to find a vendor prepared to sell the small amount typically used in telescope construction. One source that will do so is Boedeker Plastics (800-444-3485, www.boedeker.com). This company can supply PFA sheet in ⅛-, 3⁄16-, and ¼-inch thicknesses. Ask for grade 350 sheet, and expect to pay approximately $10 to $15 for 6 square inches.

Other Findings

I carried out most of my testing with the linear movement rig, which mimicked the conditions for Dobsonian altitude bearings, but I also tested some materials with a second rig that mimicked the azimuth movement of a typical Dobsonian. My tests yielded velocity curves that were slightly shallower than for altitude motion, which should translate into better movement in azimuth than in altitude for a given combination of materials.

The use of silicone-based car waxes and sprays on the laminate side of Dobsonian bearings has been advocated by

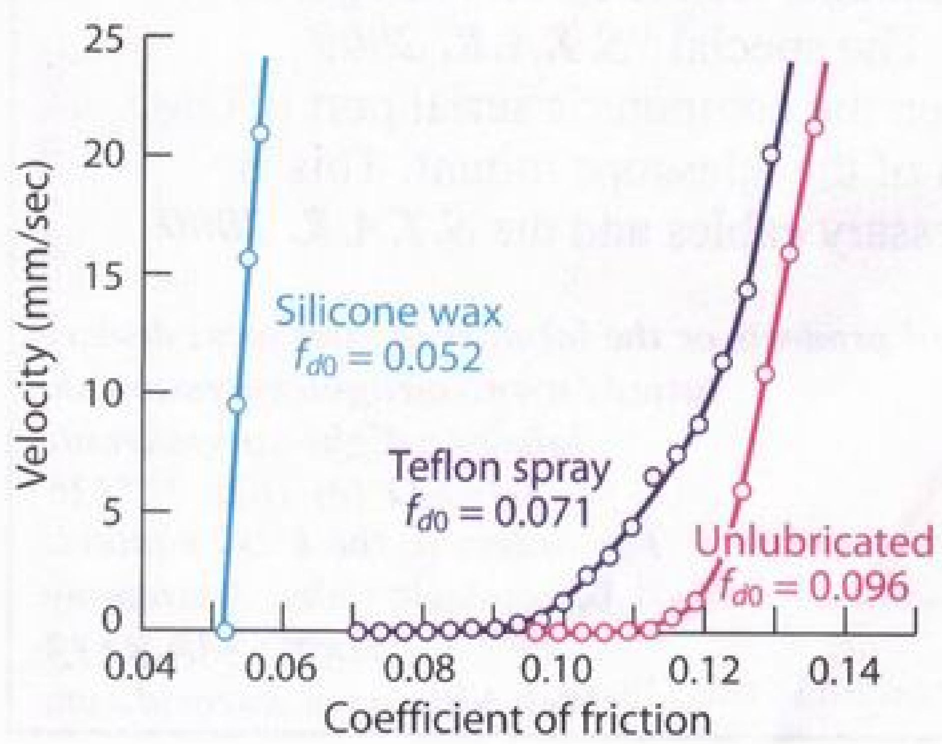


For his 18-inch Dobsonian, the author used roller bearings to supersede PFA pads for the rear altitude bearings *(right)*, of the scope's rocker box, leaving the front pads *(left)* alone. The rollers take half the weight of the tube assembly and effectively halve the friction. The combination works very well even at magnifications exceeding 500×. (The pad seen near the roller is a nonfunctioning leftover from the telescope's previous configuration.)

many as a means of improving sticky bearings. My bench tests showed that, though such lubricants radically reduce the f_d, the gradient of the resulting curve is dramatically increased, leading to significantly higher start-up velocities and an *increase* in stiction. I saw just such a detrimental effect in experiments I carried out last year on the altitude bearings of my own Dobsonian. (Luckily, the bearings were readily cleaned with Dow Corning OS-2 Silicone Remover.)

However, my test showed that dry Teflon spray *is* a lubricant that's worth trying, especially if your scope is large and heavy. As the graph below shows, dry Teflon lubricant lowers friction without significantly altering the shape of the curve. This suggests one reason why regular Teflon bearings work better in the field than my tests indicate they should — Teflon flakes off during normal use,

Teflon Against Ebony Star with Lubricants



and this would likely act very much like the dry lubricant spray.

I tested the effect of dew on several bearing materials by lightly spraying them with water. The resulting changes were less pronounced than I expected but generally led to inconsistent friction and slightly higher overall values for f_d.

Previous experience has shown that textured laminates, like Ebony Star, perform better than plain ones. I tested both Teflon and PFA pads against untextured laminate. The only significant difference I found was that f_d was 20 percent higher than for textured laminates, but the shape of the curve was essentially unchanged. I believe that the main reason that plain laminates have a reputation for inferior performance is their susceptibility to fouling from dust and other debris. With textured laminates dirt is pushed into the troughs in the surface and out of the way, whereas with untextured laminates it simply builds up. This difference between laminates didn't show up in my tests because they were conducted with clean bearing surfaces. If you keep your bearings clean, untextured laminates are worth trying.

I also tested different grades of Teflon. Mechanical-grade Teflon is less expensive because it is composed of a certain percentage of reprocessed material. Surprisingly, the sample I tested gave significantly lower friction than the virgin grade, yielding a f_{d0} of 0.048 compared to 0.062 for virgin Teflon. It is likely, however, that other samples will produce different results since there is probably significant variation from sample to sample. The quality of virgin Teflon is likely more consistent.

Comments and Conclusions

The biggest surprise in my testing was the superior performance of PFA, a material that appears to be virtually unknown to telescope makers. Another surprise was the relatively poor performance of virgin Teflon bearing against Ebony Star laminate, in spite of this combination's excellent reputation. Perhaps when used in real telescopes where other factors (Teflon debris in the bearings, uneven loading of the pads, mismatched surface profiles) come into play, Teflon may perform better. However, under controlled test conditions the results were good, if unimpressive.

There are possibly other material combinations, as yet unfound, that might yield superior Dobsonian bearings. I would be very interested to receive feedback from readers trying PFA and other bearing materials on their scopes. There's nothing like a little experimentation to pass those cloudy nights.

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