A Case for Commercial Bushings for Clocks, and How They Compare to a Theoretically Ideal Bushing

I have read numerous articles on the subject of bushings for mechanical clocks, and I have seen two demonstrations about making and installing a bushing. There is consistent argument that a custom-made bushing is superior to a commercially made bushing, such as those by Bergeon and KWM. While writers and instructors spend considerable time and effort proving this, most repairmen, being more practical than academic, and needing to find a balance between doing the best possible repair and feeding their families, turn to commercially made bushings. Little effort has been made to address the issue of using commercially made bushings. I agree that custom-made bushings would be appropriate for the proper repair of fine, high-grade, and expensive clocks if the customer were willing to pay a premium for a custom job that would match a first-class clock. However, the vast majority of clocks made after W.W.II and many bread-and-butter clocks made in history were not made as objets d'art, and repair as art would not be called for.

A custom-made bushing is produced individually, or in small batches, on a small lathe. A hole is drilled in the center. The outside diameter is reduced such that the bushing would fit in the hole like a glove. The hole is drilled at right angles to the plate, paying particular attention to center. The bushing is secured in the hole with a round-tipped punch for a tighter fit; this makes the oil sink at the same time. The ideal bushing has an oil sink the same size and shape as other comparable bushings in the plate. Further, the plate is polished to conceal the repair. The diameter of the bushing hole is increased in small steps with a cutting broach from both sides of the plate, such that the pivot could tilt by about 5° to any side from perpendicular. This approach to making bushings places more emphasis on appearance than on function or design, and it assumes that the original bushing was "ideal" in form.

Commercially made bushings are frowned upon by purists, mostly because they are visible after installation, either because they stick out beyond the plate or because they are too short. After all, a bushing so easy to install cannot be good.

I would like to consider a very common modern clock, the Hermle 340-020 floating balance, Westminster chime movement. This movement is, in my opinion, manufactured strictly as a functional piece. It performs its functions predictably and reliably. However, it makes no pretense of being a fine work of art, a masterpiece of engineering, made of the finest materials, finished by hand, an object of beauty that is pleasing to the eye. I would like to consider what would be necessary to perform a quality, functional repair of one of these movements using commercially-made bushings. I have not seen adequate literature referring to this kind of repair work.

THE IDEAL FUNCTIONAL BUSHING.

First, I would like to consider the factors that make a bushing superior, without regard to its appearance. I have seen many clocks that have been repaired with commercial bushings. They appear to be correctly installed, but close inspection reveals that their oil sinks are small or non-existent. Sometimes the bushing is longer than the pivot. Did the repairman know how to fit this bushing?

There are two main factors that determine the shape of the ideal bushing: its length and its oil sink. Its length maximizes the area acted upon by the pivot. This is of supreme importance because it is the pressure that causes the brass to give way, or wear, and the pivot to wear similarly. Since pressure is defined as the force that acts per unit area, we can reduce the pressure by maximizing the area upon which the force acts. Consider the pivot of the second wheel in that Hermle movement. Over a number of years, these pivots were made of an alloy material that was subject to developing small pits that caused premature wear. Think of this material as being able to work well within a certain pressure range, beyond which it would begin to fail: the second wheel in a weight-driven Hermle grandfather clock seems to fare noticeably better than its similar counterpart in the spring-driven movement. The fully-wound mainspring exerts much more force. While a friend of mine advocates cutting off the defective pivot and replacing it with a blue-steel pivot, I believe that if the pivot were long enough that the repairman could install a long enough bushing to reduce the pressure to a low enough level, the seemingly inferior pivot would perform satisfactorily. However, the repairman may be tempted to install a bushing longer than the pivot, which could result in tunnel-action, where wear takes place inside the bushing. As wear takes place, the pivot is displaced until the shoulder at the opposite end of the arbor pushes against the wall of the opposite bushing, and binding occurs.

The oil sink determines how much oil can be applied without runoff. If we design it such that the quantity of oil the bushing could be maximized, the bushing would last longer. I like a taper of 45°, but the shape and size of the oil sink should depend on the viscosity of the oil. A straight taper, such as on Bergeon bushings, is better for light oils. A curved oil sink, such as on many French clocks, is better for thicker oils and light greases because then more lubricant could be applied. If the pivot sticks out slightly beyond the bushing, not only would tunneling be avoided, but also more lubricant could be applied without runoff.

Another factor of much argument is the tightness of the hole around the pivot. Many repairmen like to fit the bushing as tightly as possible without binding, as if a Sessions were a L'Épée. Some repairmen recommend a side-tilt of 5º, but this does not consider the functional qualities of the particular gear, nor the thickness of the plates. For example, the fourth strike wheel needs to have a tighter bushing on the front plate because of the gathering pallet, or strike problems may occur. On the Hermle movement, this bushing could be tighter than that same bushing on the Herschede tubular bell clock because the plate of the latter is fifty percent thicker and some side-tilt is necessary to prevent binding. The front plate bushing of the Hermle chime governor needs to be tighter than the same bushing for the strike governor because the chime governor pinion is considerably smaller. The Hermle fourth time wheel needs a tighter bushing on the back plate than on the front plate because the pinion and gear are near the back plate. The second time wheel wears towards the centershaft, so its bushings need to be tighter. The third and fourth chime wheels in the Hermle grandmother and grandfather movements wear towards the fourth and fifth wheels respectively, so the third and fourth wheel bushings need to be fitted carefully to account for this. These examples should demonstrate the need for the repairman to alter his procedures to fit the needs of the gears and their functions.

I would like to use an example to illustrate how I fit a tighter bushing. The strike fourth wheel on this Hermle may need a bushing replaced at both ends. I would use a Bergeon #48 on the front plate and a #40 on the back plate. The front plate bushing needs to be tighter than the back plate bushing because of the gathering pallet. I would open the front plate bushing with a cutting broach from both sides just enough, such that when I position the back plate directly above and parallel to the front plate, the back pivot would have a side-shake to just beyond the edge of the back plate bushing in all directions. This is clearly a judgment call. However, this approach works very well for me. I would fit the back plate bushing using the 5º of side-shake rule.

If functional considerations, like those outlined above, are not affected by the tightness of the bushing, the bushing should be fitted a little more loosely. This is because there would be more room inside the bushing to accommodate more lubricant. In addition, the lubricant could circulate better than in a tighter bushing. More lubricant in the bushing and oil sink would provide better protection against foreign contaminants and against corrosion. Better lubricant circulation could draw away particles of wear from the bearing surface. Therefore, a tighter bushing is not always preferable: I expect some unwavering purists would see this as heresy. However, it not the size of the hole that causes the frictional increase in the bushing, but rather binding caused by wear and impurities in an out-of-round hole.

Many commercially made bushings have a serious design deficiency. The exterior diameter of the bushing should be two to three times that of the interior diameter for two reasons. A bushing with a wider wall can accommodate a larger oil sink. The exterior diameter of the bushing should be greater than the diameter of the pivot shoulder. I believe Bergeon makes a superior assortment of bushings for this reason.

I would like to consider whether the bushing may protrude, whether it may be longer than the plate were thick. I believe that in an inexpensive, mass-produced functional timepiece, the function becomes more important than the form, or appearance. Many clocks have thin plates, less than 2 mm. thick. If the bushing were of the same length as the plate were thick, there would be two options. The bushing could be made without an oil sink to maximize the area of contact, but this would compromise the amount of lubricant the bushing could hold. Or the bushing could be made with an oil sink, to maximize the amount of lubricant the bushing could hold, but this would compromise the area of contact and the pressure on the bearing surface could lead to premature wear and failure. Surely, the compromise of a slightly protruding bushing would be a small price to pay for increasing the durability of the bushing by fifty percent of more. Besides, if the manufacturers had not made the plates so thin, we would not have to face this dilemma.

Finally, I would like to consider the most important reason for endorsing commercially made bushings: the repair would easily be reversible in the future, should a purist prey upon it, insisting that it should be done his way only. I have seen many types of repairs that are not reversible, leaving filing marks on the plates, solder jobs, and so on. These make it difficult for a future repairman to restore the clock as original. However, the commercially made bushing could easily be removed and replaced with a custom-made bushing. I would consider such action to be questionable, but it would at least be easily achievable.

IN SUMMARY:

The ideal bushing, whether custom-made or commercial, should:

1. Be long enough to be durable, though this may be compromised by the length of the pivot,
allow the pivot to stick out slightly into the oil sink, to maximize the amount of oil that could be added.
2. Have a large enough oil sink, the size and shape of which would be determined by the viscosity of oil used.
3. Have an exterior diameter wider than that of the pivot shoulder.
4. Have a hole large enough to allow more oil in it and to allow it to circulate, but small enough to ensure appropriate functioning of the clock.

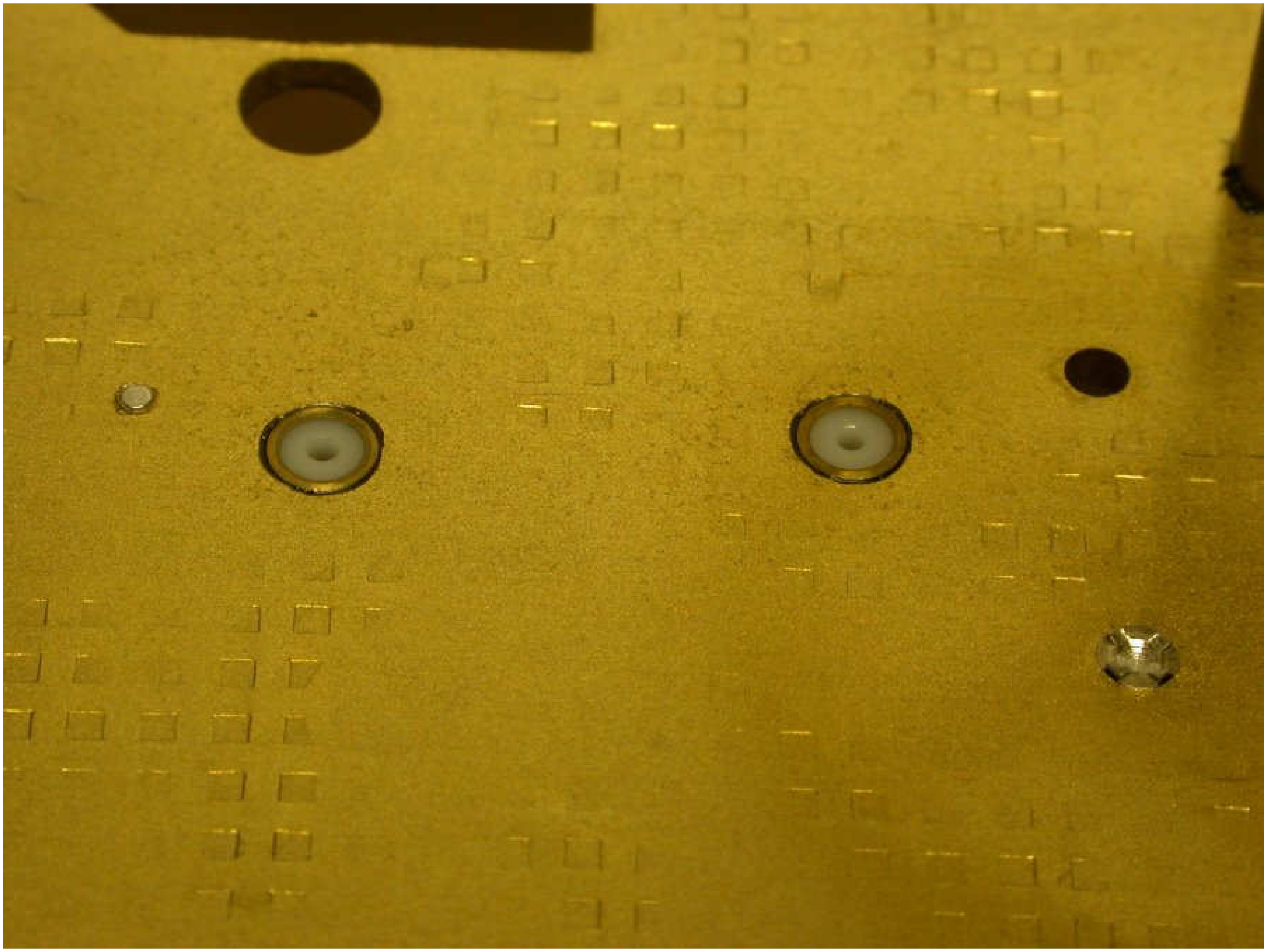
Now I would like to consider commercial bushing tools. Some repairmen believe that the hand-held tool is necessary to begin the bushing. They believe that this is the only way the reamer can be turned half a turn at time to guide the hole, keeping it centered. However, this can be achieved in the same manner using a bench-mounted tool, with the added advantage that the plate can be secured in position with clamps and the reamer is held vertically above the plate with much more precision. However, the drill stand setup for bushing work does not offer enough centering control. In addition, some drill presses are not precise, or true. It has been suggested, (Clockmaker's Newsletter , Nov. '96), that "the extra expense of the (bushing) machine just doesn't make sense," and that "there are more important pieces of equipment to find and master." Six years ago, I worked in a clock shop, the owner of which refused to buy a bushing machine because he had replaced bushings by hand for twenty years and the machine was a waste of money. He did, however, buy a new Ford van, a new Ford Mustang Cobra, and a new Ford Explorer. My bushing machine was one of my first expenses when I set up my own shop. It is one of my most cherished tools, worth every penny.

The design of the reamer itself is just as important as the handle it is in or the bench-mounted tool. I have used both the KWM (like the black reamer below) and Bergeon (like the steel reamer below) style reamers. I have found that the tip of the Bergeon reamer is shaped differently, with the result that the reamer appears to be self-centering in the oil sink to some extent, even when the hole is worn oval to one side. While it is necessary to make sure that the reamer is centered anyway, because an off-centered oil sink would offset the reamer, I have found that this better-designed reamer makes centering so much easier.

I would like to end this essay with a quote I recently saw in the Clockmaker's Newsletter, from Dr. Joseph Baier in his book Striking Clocks:

Bushing work, if properly done, is neat in appearance, as good as or better than the original, is functional, properly located for a near perfect fit for wheel and pinion meshing, can be broached to size, and further, when wear occurs in the future, the old bushing can be pressed out and a new one pressed in.

Update: here is a photo of what look like nylon bushings, very unusual and therefore noteworthy, found in a Swiss Bucherer clock, circa 1985. When the arbors have steel pivots, however, I prefer brass bushings.



Mark Headrick