A tailstock sensitive drilling attachment

Guy Gibbons

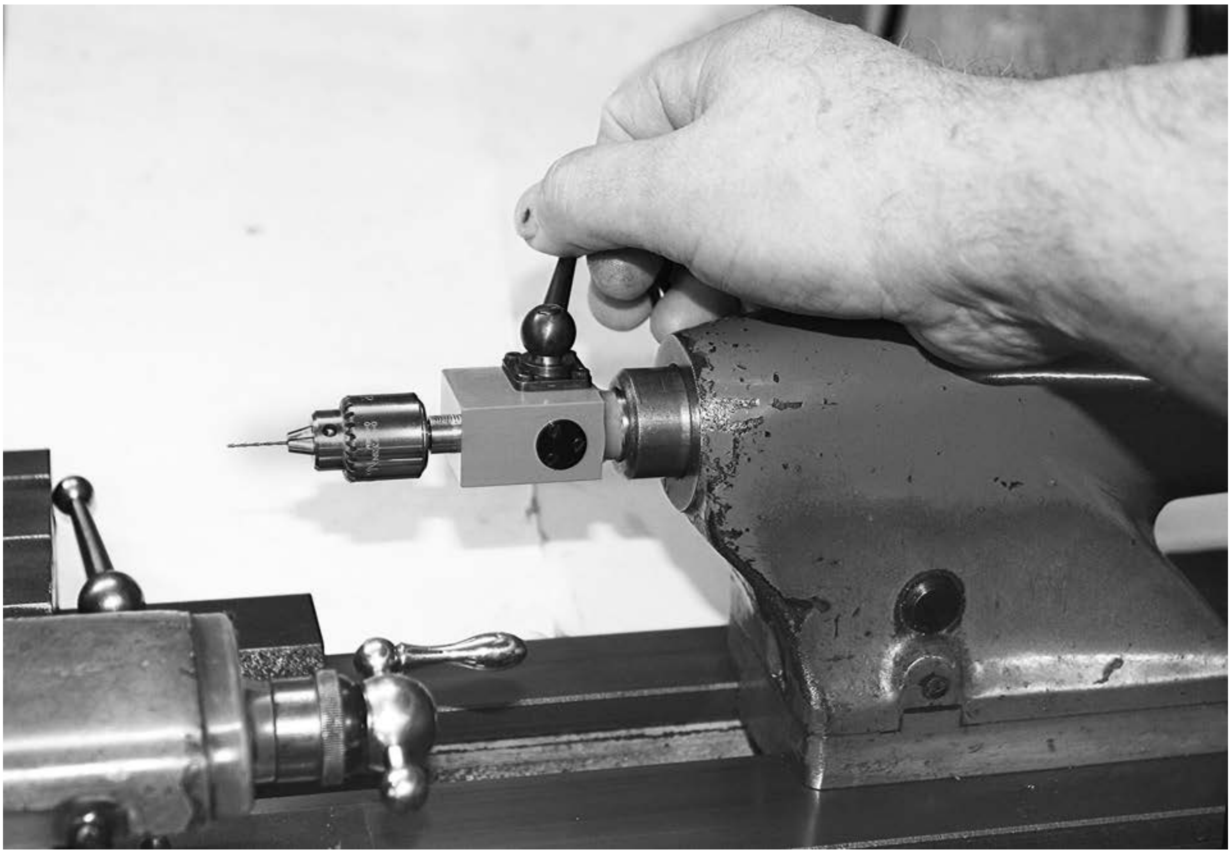


Figure 1 Using the sensitive drilling attachment in the Myford Super 7 lathe

Introduction

Although no doubt eminently suitable for the purpose, I have never liked the cumbersome linkage designs of sensitive drilling attachment generally offered for use in the lathe tailstock. To me, they look ugly.

The attachment described here is essentially a miniature rack-feed device; not only do I find it works well but its compactness and style makes its use satisfying for the more discerning lathe user.

Design

The attachment requires the ability to cut a rack and mating pinion, but has few other challenges for the competent machinist. Fitted with a 0 to $^{5}/_{32}$ inch (0 to 4 mm) capacity Jacobs drill chuck, loading is low especially at the size of drill with which it will be used (typically 1.5 mm or less).

The body

The body is machined from a piece of square or rectangular steel section not less that $^{13}/_{16}$ x 1 $^{3}/_{16}$ inch. With a little tweaking you should be able to get it out of 30 mm square section or even 30 x 20 mm rectangular section, though being a little small some modification will be needed to one or two of the dimensions.

After having brought the section to size by milling or fly-cutting, a No.2 Morse taper is machined on one end. I use the taper turning attachment with which my Myford lathe is fitted – Figure 2 – but it is just possible to machine the taper using the top slide. Taper turning to precise dimensions is not easy, and the best way to check the taper angle as it nears the finished size is to use a No.2 to 3 Morse taper sleeve and high-spot blue. I find that some fine adjustment with a file and finishing paper may be needed, aiming to make the taper if anything very slightly hollow at the mid-length of its taper.

If using a taper turning attachment, the topslide can be set over to 6 degrees to give a tenfold reduction in the in-feed compared to what it says on the graduated feed collar. Mathematically, sine 6 degrees ≈ 0.1 so a 20 thou feed as indicated by the topslide collar means a 2 thou actual depth of cut. Effectively it is a sensitive feed.

Once the taper is finished and without removing the body from the 4-jaw, the small end of the shank is finished. The end is centred and drilled $^{13}/_{64}$ inch diameter to a depth of $1^{1}/_{4}$ inches, this depth being necessary if a standard length reamer is to be used (from the other end) for finishing the $^{3}/_{8}$ inch bore in which the quill slides. The end is then threaded, and once satisfied that the root radius at the large diameter of the taper is good, the body can be removed from the chuck. The body is then set up in the lathe headstock taper and, after facing off the end to the correct length, the quill bore is centre-drilled, drilled and reamed $^{3}/_{8}$ inch right through.

The next tricky job is to bore the body for the feed pinion at the exact separation distance from the quill. Initially I marked the spindle centre to the nearest 5 thou with a square, scriber, vernier calipers,, a bore gauge and a micrometer were all used to get the final bore to as near their correct centres as possible. I find accuracy in scribing is aided by using a 3x magnifica-

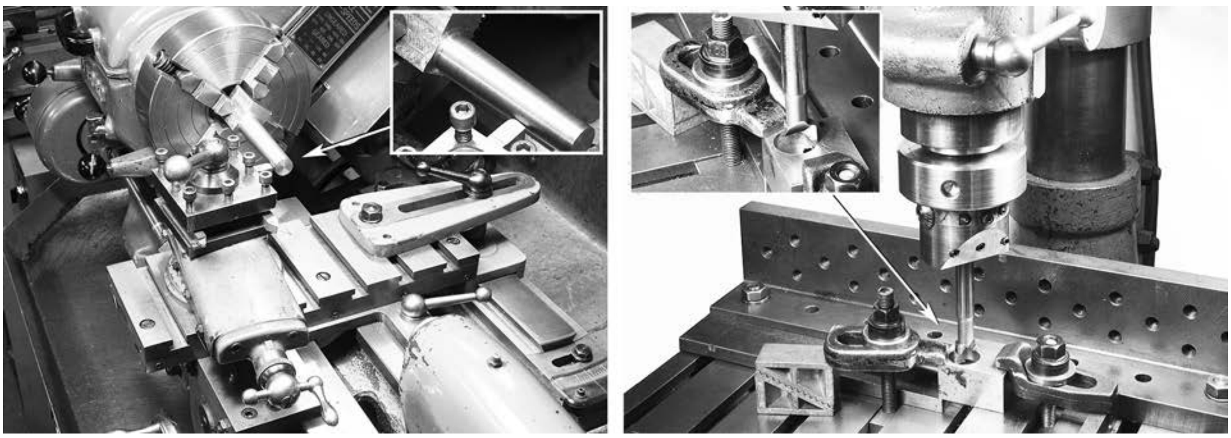


Figure 2 Turning the No.2 Morse taper using the lathe taper turning attachment, and (right) boring the body for the feed pinion spindle

tion jeweller's loupe. Even if one could get the centres perfectly correct by drilling and reaming, boring with a single-point tool will be necessary to remove any 'wander' of the drill caused by it breaking into the quill bore – Figure 2, right.

The quill

The quill needs to have rack teeth cut on it for which I used a standard 1.0 mod No.1 involute gear cutter. Unlike wheel and pinion cutting, the infinite pitch circle diameter of a rack means that each tooth has to be indexed linearly.

For 1.0 mod gears, the pitch is simply π (pi) mm, i.e. 3.14 mm or, if your machinery has imperial graduations as mine do, 0.1237 inches. The other thing about cutting a rack is that it is not amenable to being cut in a vertical milling machine, so I cut mine in the Myford lathe, and the set-up I used is shown in Figure 3. Note the lathe is being run in reverse, and the feed is vertically upwards using the vertical slide. After each cut, the saddle is advanced 0.1237 inches by the lathe leadscrew handwheel at the right hand end of the lathe bed.

At this point some will wonder why I use metric gears when everything else in my workshop is imperial. The reason is simple if indefensible; like ball bearings which are far more common in metric sizes, I chose to purchase a set of metric gear cutters. But imperial DP (diametral pitch) gear cutters could be used if preferred.

To hold the quill I slotted it into one of the vertical slide $^3/_8$ inch wide tee-slots, packed out behind with a $^1/_2$ x $^1/_8$ inch length of rectangular section. This ensured everything was square and parallel, but had the disadvantage that the quill could not be rotated through an accurate angle (180 degrees) for cutting the keyway (more of which later). I am sure other clamping arrangements are possible, but it is not an easy one to solve and still leave space for the clamping dogs or (as in my case) the toolmaker's clamps.

Incidentally, Myford owners will perhaps notice that I fitted my fixed vertical slide with a replacement table designed for their swivelling vertical slide to give it extra width for clamping work. I recommend it as a well-worthwhile modification, not least because toolmaker's clamps can be used on the overhanging sides. Moreover, in set-ups such as this, the wider table

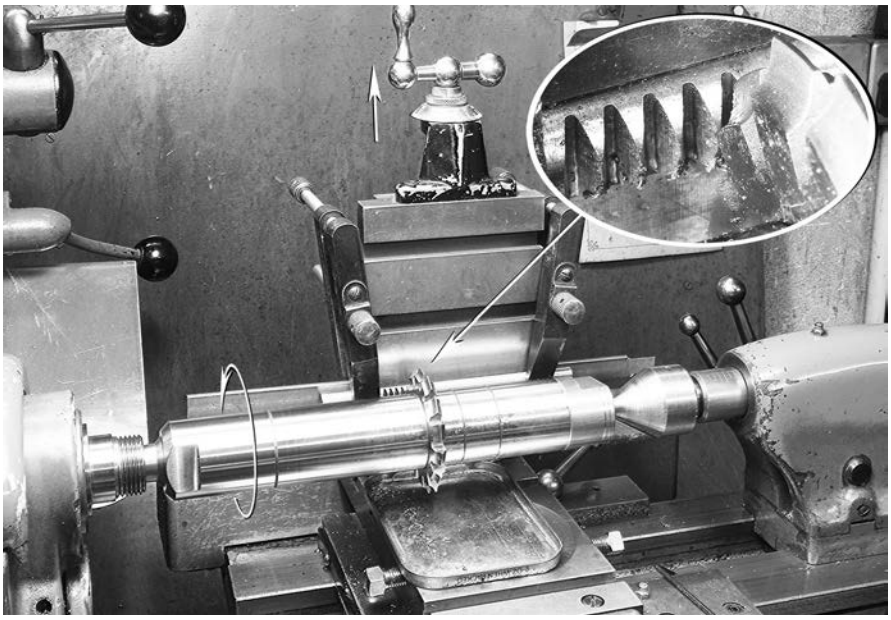


Figure 3 Cutting the 1.0 mod rack teeth on the quill

width will also allow a larger width of the work clear from clamps and dogs to be presented to the cutter.

The spindle and bearings

The spindle is a simple turning job, but does need a 12 tooth 1.0 mod pinion cut on it. It is cut in the dividing head on the vertical milling machine using a No.8 involute cutter – Figure 4. The taper for the proprietary Myford handle is machined to match using a specially made taper D-bit reamer; mine has a 13 degree half-angle.

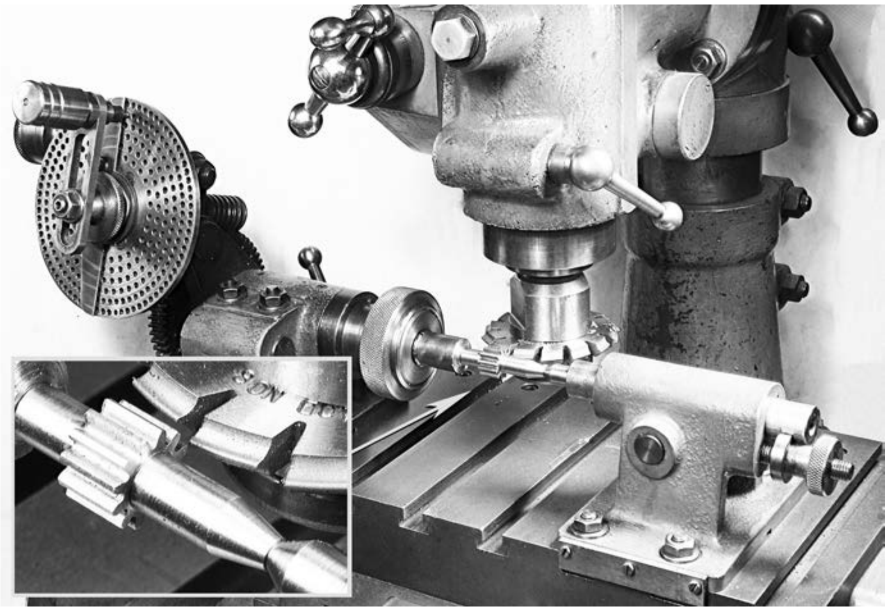


Figure 4 Cutting the 12 tooth 1.0 mod pinion on the feed spindle

The spindle bearing housings are machined from 20 mm (0.787 inches) square mild steel bar initially gripped in the 4-jaw chuck to turn the register before parting off. With the cover now held by its register in the 3-jaw, I used my cross-slide milling attachment to drill the 6 BA securing holes on a $^{13}/_{16}$ inch PCD followed by a $^{3}/_{16}$ inch diameter slot drill to produce the counterbores. The square was set up using a set-square on the lathe bed, before indexing $7^{1}/_{2}$ turns of the dividing plate's 60 division (hole) ring to drill the first hole (and 15 turns thereafter). If using a non-piloted cutter such as a slot drill as I did, providing the radiused nose of the upper spindle bearing housing is not yet cut – Figure 5, it is good to start the counterbore with a $^{3}/_{16}$ inch drill so that the slot drill is centred on the hole. The counterbore depth is controlled by engaging the saddle feed nuts and feeding from the feedscrew handwheel.

The body is drilled and tapped for the securing screws from the covers. The upper housing nose can now be turned; to do so earlier would make it more difficult to drill and counterbore the securing screw holes. The bronze shell bushes are held in place with Loctite.

At this point a preliminary assembly is called for when it may be found that the centre distance between the spindle and the rack is incorrect. If it is tight, then it is a matter of re-mounting the rack and cutting the teeth a little deeper, but if it is too loose then one probably has to re-cut the rack. An alternative might be to fit eccentric bronze bushes to the bore of the bearing housings. Mine was too tight, so I chose the former, primarily because I deliberately did not finish the quill before I could check its fit (i.e. initially I just cut the rack teeth without finishing the chuck taper, bore, etc.).

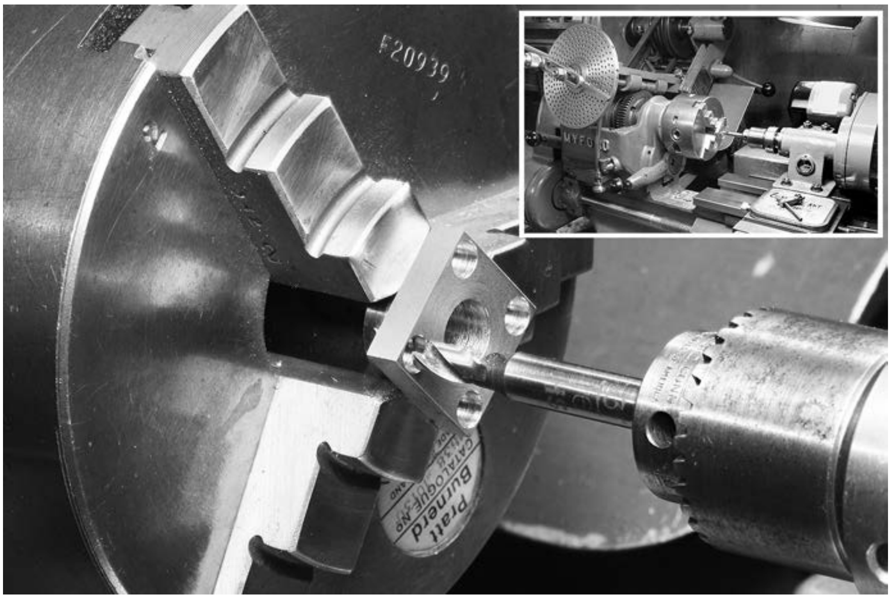


Figure 5 Counterboring the upper spindle housing to reduce the protuberance of the hex. skt. cap screw head

As to the desired fit, backlash should be as little as possible consistent with smooth action, and the important thing is to ensure the quill slides freely when operated by the spindle; if it does not, sensitivity will be lost. The quill return spring (the tension spring) will help to keep backlash under control. One thing to make sure of is that the tips of the rack teeth are no higher than their correct addendum (1.0 mm) or they will bind in the gaps between the pinion teeth leading one to suppose that the pitch centres need greater separation when they do not.

I have not given the matter a great deal of thought, but it might be possible to purchase a commercial pinion and fit it onto the spindle arbor with, say, Loctite. Moreover, as involute rack teeth are straight-sided, it would also be possible to cut the rack teeth with a fly-cutter. Adopting these practises would avoid the need to invest in gear cutters.

Finishing the quill

Once satisfied with the rack tooth depth and its action with the spindle pinion, the No.0 JT (Jacobs taper) is turned on the nose with the top slide set over, checking the fit in the chuck with high-spot blue.

The key and keyway caused me some deliberation. Firstly, did I need one or would the engagement of the rack with the pinion provide all the necessary rotational constraint to the quill? I decided that relying on the mesh of the gearing was unwise, and a trial assembly did give a lack of smoothness to the feed. The next matter was whether the key could be a simple round (dog-point) screw. Even though the loading was light, I decided that any bruising the edge of the round dog-point created on the edge of the keyway might give rise to a lack of smoothness in the feed. This left a rectangular key as the only option, providing (in theory) a true surface of contact (rather than a line of contact) for rotational constraint.

The keyway in the quill is cut using a $^{3}/_{32}$ inch woodruff cutter in the milling machine with the quill held between centres in the dividing head and matching tailstock. Care must be taken to get it exactly opposite the centre of the rack teeth which, by cutting the rack with the spindle clamped to the vertical slide, meant I had no way of precision-indexing it through 180 degrees (constructors may wish to consider a way of cutting the rack teeth while the quill is held in a dividing head). Even taking care, my keyway was about 3 thou off-centre, but by making the key slightly asymmetric, I was able to alleviate the problem so the quill slid smoothly and with only the merest hint of quill rotational backlash (probably no more than about ± 0.5 degrees).

The nut for the back end of the No.2 Morse taper is designed partly to get the overall length of the taper to a dimension that will ensure the taper self-ejects from the Myford Super 7 tailstock and partly to provide a recess for the anchorage for the tension return spring. The return spring could be omitted, but it helps to reduce the possibility of a delicate drill tip from snatching in the work that might lead to breakage. I used a 6 mm diameter by $1^{1}/_{2}$ inch overall length tension spring wound from 26 gauge steel wire (0.018 inches (0.45 mm) diameter wire); this is probably a little light and it could be usefully made from a slightly thicker gauge of wire (say 24 gauge).

All that remains is to finish the quill to length and drill for the return spring. The forward limit of travel stop is provided by the pinion teeth locking at their end of engagement with the rack teeth (not ideal but not of great importance), while the backward limit is provided by the end of the quill abutting the plug at the end of the Morse taper. I also engraved some graduations at $^{1}/_{32}$ inch intervals on the first $^{5}/_{8}$ inches of the nose of my quill, but these are not shown on the drawings. If you choose to do this, mine vary in wrap-around length from 30 degrees to 42 degrees for the $^{1}/_{32}$, $^{1}/_{8}$ and $^{1}/_{4}$ inch divisions respectively. and these divisions can just be seen in Figure 6.

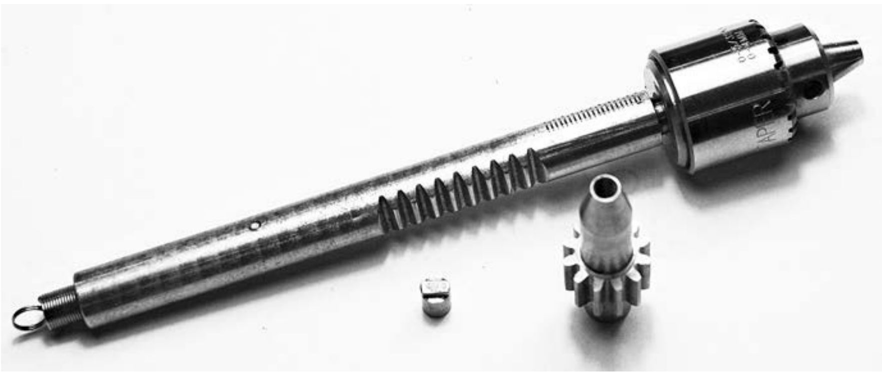


Figure 6 The completed quill, pinion spindle and key

The lever handle

The lever handle is a ball handle turned using a radius cutting attachment. The handle fits onto the spindle using the same taper angle as that used by Myford for fitting their feedscrew handles. The sequence of photographs in Figure 7 shows some of the steps I used to make my ball handle.

Final assembly

A thin piece of bent wire will be needed to pull out the outer end of the tension spring to enable the brass pin to be located in the recess in the body nut. One other detail worth getting right is that you press on the Jacobs chuck so that one of the holes for the key is in the vertical position. Painting and/or bluing of components is, of course, at the constructor's choice.

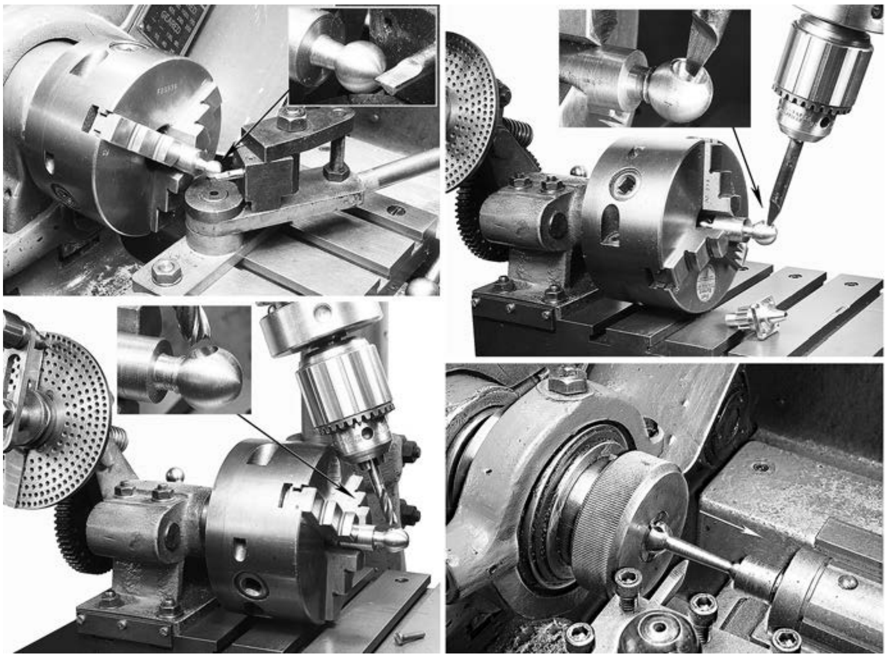


Figure 7 Steps in making a ball handle. The radius cutting attachment top left pre-dates the spherical turning attachment that I now use

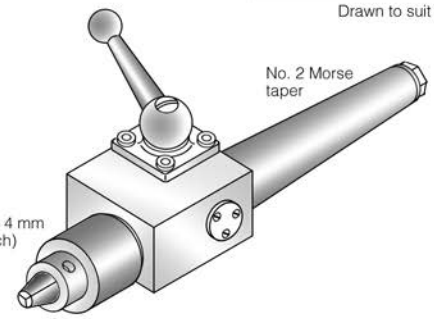
Figure 8 The completed attachment before painting and finishing

Using the attachment

For the avoidance of small drill breakage, I have found that sensitive feed is far more important than high speed (see Appendix), and the ball handle provides that sensitivity. Little else need be said, and made with a good degree of precision, I think constructors will be please with its usefulness.

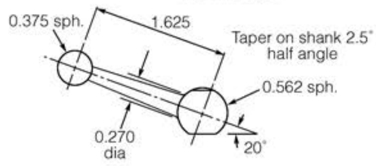
Sensitive drilling attachment

Drawn to suit the Myford Super 7 lathe



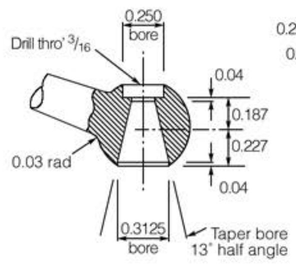
Ball handle

1 off mild steel



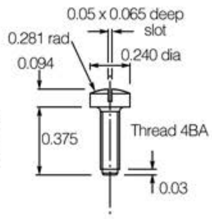
Detail of large ball

scale 2x



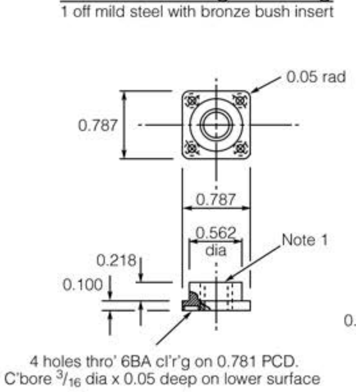
Screw

1 off steel



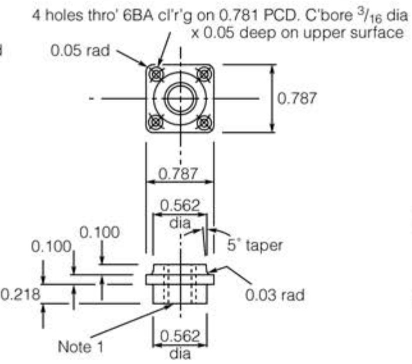
Lower bearing housing

1 off mild steel with bronze bush insert



Upper bearing housing

1 off mild steel with bronze bush insert



NOTES

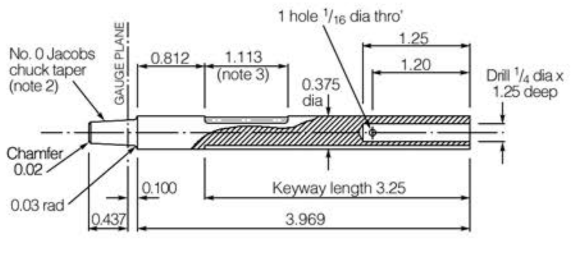
1. Ream central bore 3/8 inch thro'. Fit full length bronze bush reamed 5/16 inch thro' x 3/8 inches outside diameter and secure with a medium strength anaerobic adhesive
2. Standard parts: 8 off 4BA x 3/16 hex. skt. cap screws

Third angle projection. All dimensions in inches unless stated. GEG 2/17(1)

Sensitive drilling attachment

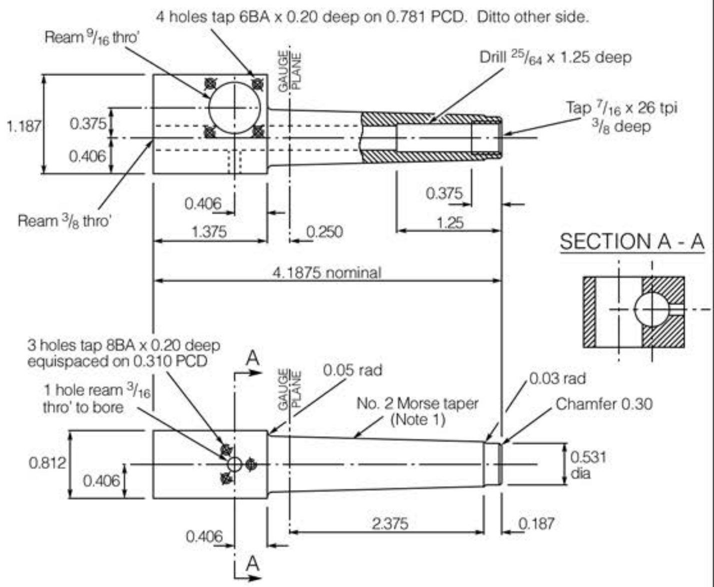
Quill

1 off steel



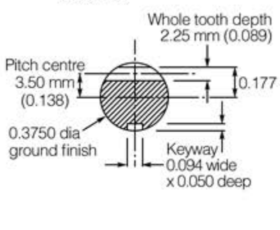
Body

1 off steel



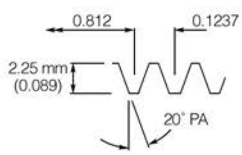
SECTION B - B

Scale 2x



Detail of rack thread

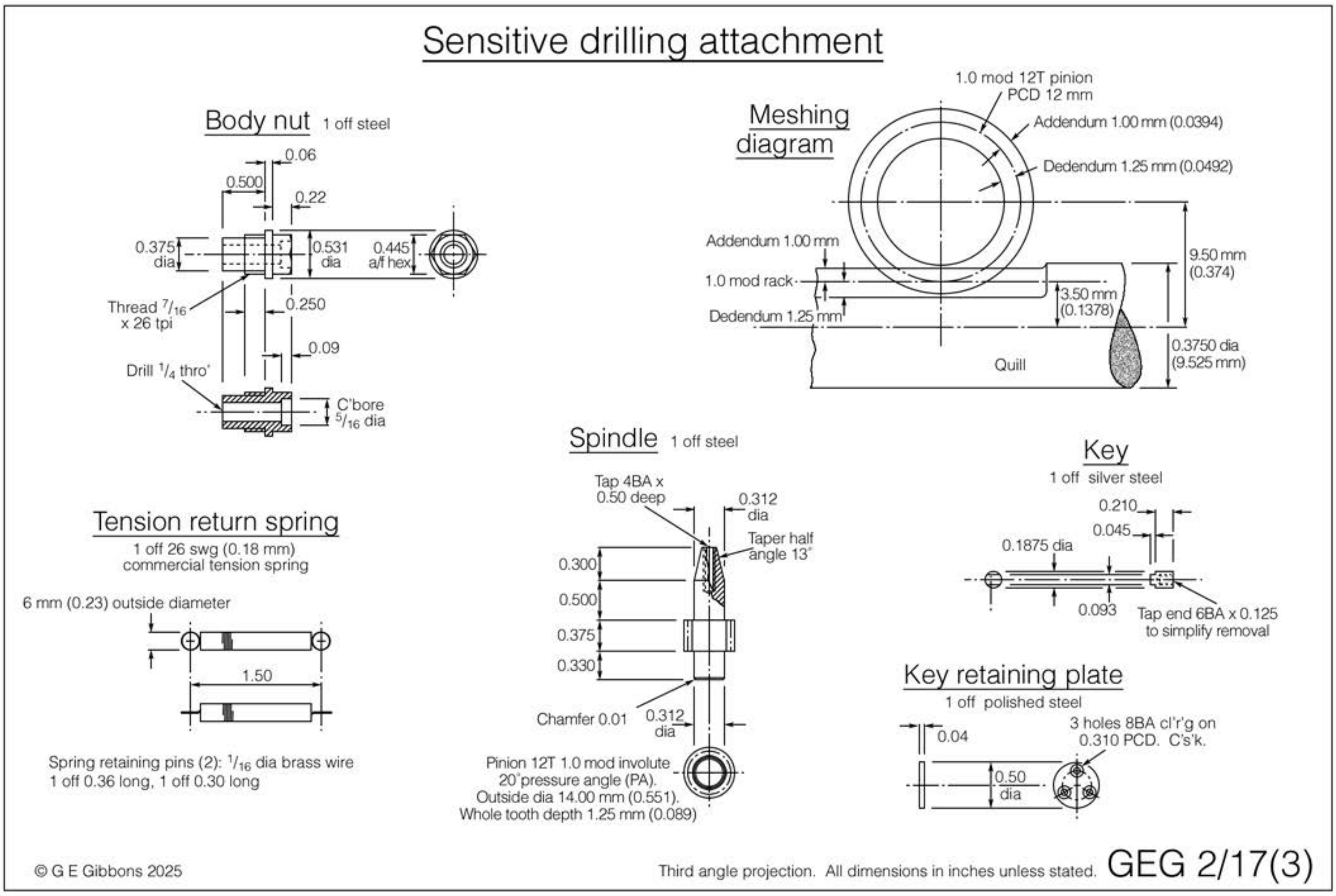
(note 3)



NOTES

1. No. 2 Morse taper to BS1660:1972. Dia. at gauge plane 0.7000, taper on diameter 2°51.68'
2. No. 0 Jacobs chuck taper. Dia. at gauge plane 0.2500, taper on diameter 2°49.40'
3. Rack 1.0 mod involute 20° pressure angle. 8 fully formed teeth (9 spaces). Overall length between centre of first and ninth space 1.1133. Tooth pitch 0.1237 (3.142 mm)
4. See Sheet 3 for rack and pinion meshing diagram
5. Standard parts: 3 off 8 BA x 5/32 steel c's'k screws parallel brass pin 1/16 dia x 0.36 long (see sheet 3).

Third angle projection. All dimensions in inches unless stated. GEG 2/17(2)


Sensitive drilling attachment
Body nut 1 off steel
0.06
0.500
0.22
0.375 dia
0.531 dia
0.445 a/f hex
Thread 7/16 x 26 tpi
0.250
0.09
Drill 1/4 thro'
C'bore 5/16 dia
Meshing diagram
1.0 mod 12T pinion PCD 12 mm
Addendum 1.00 mm (0.0394)
Dedendum 1.25 mm (0.0492)
Addendum 1.00 mm
1.0 mod rack
Dedendum 1.25 mm
9.50 mm (0.374)
3.50 mm (0.1378)
0.3750 dia (9.525 mm)
Quill
Spindle 1 off steel
Tap 4BA x 0.50 deep
0.312 dia
Taper half angle 13°
0.300
0.500
0.375
0.330
Chamfer 0.01
0.312 dia
Pinion 12T 1.0 mod involute 20° pressure angle (PA). Outside dia 14.00 mm (0.551). Whole tooth depth 1.25 mm (0.089)
Key 1 off silver steel
0.210
0.045
0.1875 dia
0.093
Tap end 6BA x 0.125 to simplify removal
Tension return spring
1 off 26 swg (0.18 mm) commercial tension spring
6 mm (0.23) outside diameter
1.50
Spring retaining pins (2): 1/16 dia brass wire 1 off 0.36 long, 1 off 0.30 long
Key retaining plate
1 off polished steel
0.04
3 holes 8BA cl'r'g on 0.310 PCD. C's'k.
0.50 dia
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Third angle projection. All dimensions in inches unless stated.
GEG 2/17(3)

Appendix

Originally thinking that high speed was essential for sensitive drilling, I designed and made a precision motorised ball bearing spindle for the lathe tailstock that was capable of smoothly delivering a maximum 13,000 rpm. Taking twist drills down to 0.5 mm diameter in an ER8 colleted spindle, it was not a success partly because of the lack of feed sensitivity but mainly because preventing the drill bit from burning-up was very difficult without the use of flood coolant. This is perhaps not surprising given the high power that accompanies high speed, the heat generated from drilling all having to be dissipated at the drill tip*.

* The heat essentially comes from the heat generated by chip formation plus frictional heat in a bore increasingly being filled with chips of cut metal. Lubrication helps to reduce the frictional heat, but heat removal and chip clearance really does need some form of flood or (better) forced coolant.

My design is pretty cumbersome, and if I were to attempt a revised version, a good starting point might be to study in greater detail dental handpieces with brushless motors made by, for example, the Swiss company Bien-Air, these incorporating a forced coolant spray directed at the drill tip and workpiece (i.e. the patient's tooth).

Nevertheless for those interested in experimentation, the assembly drawing and selected photographs included below should give constructors some thoughts on how not to do it.