Milling appliances *Continued from February 15* ***By NED***

ROTARY SPINDLE for the small lathe

ROTARY spindles for driving drills and milling cutters in the lathe vary from the simple fly-cutter arbor, running between centres in a cutter frame, to much more elaborate appliances with specially designed bearings and collet chucks. Each of them is capable of good work within its particular limitations. From experience with most of them, I have attempted to design one which is adaptable and versatile, so that it will cope with the widest possible range of operations on a small lathe. It is intended to be interchangeable with the indexing spindle unit already described, for mounting in either the plain or swivelling quill holder.

I have given much thought to the possibility of adapting a single spindle unit for indexing and driving cutters, but it is difficult to combine the most useful features of the indexing spindle, including the use of standard lathe mandrel fittings, with the free running and precision of a high-speed rotary spindle. While we can use the indexing unit as a milling spindle by fitting a driving pulley in place of the change wheel, the type of bearing is not best suited for running at high speed, and its friction is greater than it should be in view of the limited power.

I consider that high speed is absolutely essential to the success of rotary milling appliances of this sort. While we may have to run some cutters at low speed, and to introduce reduction gearing to the spindle in order to obtain sufficient torque for driving them, most operations can be carried out more accurately, and with better finish, by light rapid cuts. Even with the most primitive cutter spindles, speeds up to 3,000 r.p.m. or more can be used with advantage, but to stand up to such speeds indefinitely an adequate bearing area and good lubrication are essential.

Opposed-cone bearing

The bearing which has long been favoured for high speed and precision, both for light lathes and milling appliances, is the double opposed-cone type, in which radial loads are taken on acute-tapered journals, and end thrust loads on integral obtuse-angled collars. But this is a difficult bearing to machine and fit properly, as the two angular surfaces must register exactly and simultaneously in their bush. If this is done properly, it is one of the best machine tool bearings ever produced; if not, it is one of the worst. Some attempts to use it (not only by amateurs) have been utter failures.

When a tapered journal bearing is used with an independently adjustable thrust surface, construction can be simplified. I have experimented with tapered bearings of varying angle from 5 to 30 degrees included angle, and with different thrust bearings, including axial and angular-contact ball races. Standard races of suitable dimensions for a compact milling spindle are apparently unobtainable, but a plain thrust ring, opposed to a fairly acute-angled journal, has been found to give excellent results for all but the highest loads. This is the bearing which I recommend

The spindle is designed to take standard 8 mm. collets, obtainable ready made for use in watch and instrument lathes; the essential dimensions for fitting them are shown, and the particulars for other sixes of collet can be found in the ME Handbook.

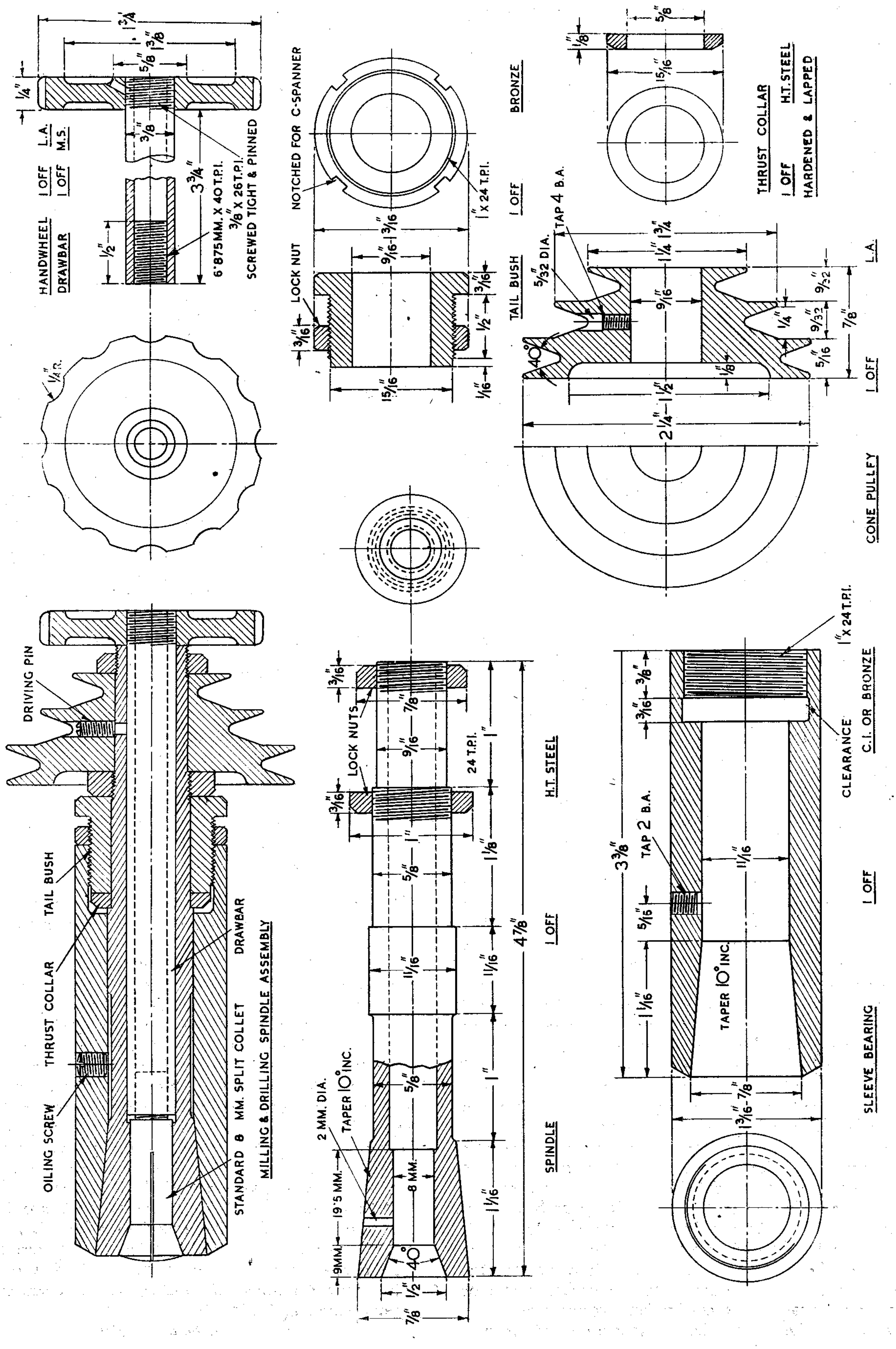
For the sleeve bearing, which is turned externally to the same size as the bearing of the indexing mandrel, cast iron is the best material, but bronze or other good bearing metal is also suitable. If extra length is allowed for chucking, both outside and inside may be machined at one setting. Back centre support can be used for the outside. In the boring of both the parallel and tapered surfaces, a fixed steady on the outer end of the sleeve will be found helpful. It is essential that these surfaces should be as smooth and accurate as possible. After the sleeve has been parted off, it is reversed for counterboring and internal screwcutting.

Getting concentric truth

For concentric truth in the second setting you may use a plug mandrel with a taper to match the bore, and a parallel pilot end may be used, or the sleeve may be held in the chuck and clocked over the outside to the highest possible accuracy. With either method. the fixed steady can again be applied to support the end while you are machining. I recommend 24 t.p.i. thread as for other screwed parts, but other pitches can be used if they are more convenient. Coarse threads should be avoided, as they increase the risk of error in concentricity. A clearance recess provided behind the thread allows the tool to run out into space, and eliminates the danger of digging in.

While the spindle is intended to be made of high tensile steel, a good machining quality mild steel will give reasonable wear. In machine tool practice, spindles are usually hardened and ground, but these processes are not generally for the amateur. Open-hearth casehardening involves the risk of distortion. Chrome deposition to a depth of not more than 1 or 2 thou will provide a hard surface without distortion, but if after-treatment of any kind is to be avoided your best course is to use steel of the highest quality, preferably an alloy or high carbon steel.

Preliminary roughing of the spindle may be carried out between centres, after which the spindle may be chucked at the large end for drilling and boring, with a fixed steady again used on the projecting end, and the chuck end clocked for exact truth. You should drill undersize and finish to size with a D-bit. If you do not have a specially long drill, to reach the depth of nearly four inches, a shorter drill, turned down on the shank, and brazed into a length of tube, will serve still better, as the tube can be used to inject cutting lubricant. Great care is needed in centring and starting the


HANDWHEEL 1 OFF L.A.
DRAWBAR 1 OFF M.S.
6·875 MM. X 40 T.P.I.
3/8" X 26 T.P.I.
SCREWED TIGHT & PINNED
NOTCHED FOR C-SPANNER
1" X 24 T.P.I.
LOCK NUT
BRONZE
TAIL BUSH 1 OFF
TAP 4 B.A.
5/32 DIA.
THRUST COLLAR
1 OFF H.T. STEEL
HARDENED & LAPPED
CONE PULLEY
1 OFF L.A.
DRIVING PIN
TAIL BUSH
THRUST COLLAR
OILING SCREW
DRAWBAR
STANDARD 8 MM. SPLIT COLLET
MILLING & DRILLING SPINDLE ASSEMBLY
LOCK NUTS
24 T.P.I.
2 MM. DIA.
TAPER 10° INC.
SPINDLE
1 OFF
H.T. STEEL
TAP 2 B.A.
TAPER 10° INC.
CLEARANCE
C.I. OR BRONZE
SLEEVE BEARING
1 OFF

drill, as any initial error will worsen as the depth of hole increases. The D-bit, which is easily made from silver steel rod, has a natural tendency to produce a true bore, but it will not correct a badly drilled hole. A chamfer should be provided at the mouth of the hole for centring.

After drilling the deep hole reverse the spindle, with the same precautions to ensure truth at both ends, and drill and bore it to fit the collets. The important point to observe is the ***boring*** of the mouth of the hole to the correct size and angle and to perfect smoothness. To mount the spindle for finishing the outside, turn a piece of material in the chuck to form a dummy collet, with the pilot end a press fit in the spindle bore. With the spindle mounted on this, and supported by the back centre at the small end, the concentric truth of the bore is assured.

In the external machining, the fit of the parallel and tapered journals is extremely important. The parallel journals can be finished by lapping, but this process is not satisfactory for the taper bearing, which must be machined to provide a perfect contact over the full length of its mating surface in the sleeve. You can check with marking colour. After getting the most accurate tool finish possible, you may remove the final high spots by a dead-smooth Swiss file. The exact end location of the spindle in the sleeve is less important than a perfect surface fit. Leave the screwcutting on the tail end of the mandrel, and the fitting of the tail bush and driving pulley, to the last.

Drawbar for collets

For standard pull-in collets, a drawbar and handwheel will be required. They are simple to make, and can be altered according to convenience. The essential details and dimensions are shown in the drawing. As the thread in the end of the drawbar must, of course, fit the thread of the collet, you may have to make a special tap unless you can get one of the drawbars used in the clock tool trade and adapt it for length. A hollow drawbar is not generally needed for a milling spindle, but there are occasions when it may be useful.

To ensure concentric truth on the 'end face and inside and out, turn, screwcut and bore at one setting. It should be a running fit on the spindle, but without any tendency to bind when it is adjusted and locked up; a little extra clearance is better than excessive friction. The flange of the bush, and also the edge of 'the lock nut, may be notched to take a C-spanner, as for the adjusting collars of the indexing spindle. There is no real need to limit the diameter of these parts, as the spindle assembly is inserted in the quill holder from the reverse end, but it is just as well to maintain some uniformity. The side faces of the lock nut should be machined true with the thread. This applies also to the spindle lock nuts; you can make them hexagonal for convenience in adjusting them with a thin spanner.

For the thrust collar, I suggest an oil-hardening steel, but mild steel; if it can be case-hardened without distortion, is quite suitable. The collar can be machined from bar and parted off at one setting, with the entering end of the hole slightly chamfered, so that it will be sure to go right home against the shoulder on the spindle. At this point it should. be a light press fit, but the rest of the surface may be slightly eased down for convenience in fitting. After being hardened, the collar should be lapped true on both the front and back surfaces, and checked for parallelism with a micrometer. A piece of plate glass, smeared with fine carborundum or emery paste, is suitable for these flat lapping operations.

The driving pulley is another component which is subject to modification; the details and dimensions shown are suitable for general purpose. It will take either $\frac{3}{16}$ in. round belting (Whiston's plastic belting is specially suitable) or endless V-belts of $\frac{1}{4}$ in. section. The angle of 40 degrees 'inclusive, with the bottom of the groove clear of the belt, gives the most efficient belt grip possible. Many pulleys are made with too obtuse a groove angle, allowing the belt to bottom, with excessive slip and loss of efficiency. The pulley is mainly driven by friction between the two lock nuts 'on the spindle, but a driving pin is also fitted (after end locations are adjusted). It consists of a 4 BA steel screw with the end turned down to fit a $\frac{1}{8}$ in. hole in the spindle. You had better drill the tapping hole in the pulley, and counterbore it to $\frac{5}{32}$ in. diameter, before the groove is fully turned, or you may find it difficult to start the drill. A hole is also drilled in the taper part of the spindle to take the collet locating pin, which should be a light driving fit, and of such a length that it neither projects above the journal surface, nor fouls the keyway in the collet when fully home. Very little force is required to drive the collet or the spindle itself, and though more elaborate keying arrangements are often used I have not found them necessary.

An oil hole is drilled in the sleeve bearing and tapped to take a short 2 BA grubscrew, so that you can close it against the entry of dirt after you have fed in oil. It should not be tapped right through; there is then no risk that the screw will foul the spindle. In the assembling of the unit, the spindle is first inserted in the sleeve and the thrust collar threaded on the small end; it may be pushed truly home by being screwed in the tail bush. Bring the spindle into its taper seating so that it tends to jam, and then adjust the bush so that it is just barely free again, and lock it in position. Put the front locking nut and the pulley on the spindle and adjust the nut to working clearance, when the back nut can be locked against the pulley. The adjustments should be made with the spindle dry, but when the work has been completed oil can be fed in to fill the space around the relieved part. A light low-viscosity spindle oil, such as Shell Vitrea (as recommended by Myford for lathe bearings) is suitable. After the spindle has been run in until the oil no longer comes out black, some slight readjustment, in the same order as before, may be necessary. You will probably find it better to dismantle the parts and examine them for high spots-perhaps more than once.

With the 8 mm. collets, the spindle will take cutter shanks or arbors up to $\frac{1}{4}$ in. dia., which is large enough for most operations within its range. You may fit larger arbors, with extension for overarm centre support, by machining the driving end to match the collets, and locking them in with the drawbar. The smaller collets are useful for holding dental burrs and similar cutters, and single-point end mills (virtually D-bits) which can be made in a few minutes from high-speed or silver steel rod. At least one ***arbor*** should be provided with a cross hole to hold fly-cutters for cutting clock wheels and pinions. Grinding wheels can be used to a limited extent, but for really effective grinding with tiny wheels much higher speeds-ro,ooo to 20,000 r.p.m.-are necessary, and these are almost impossible to obtain except with specialised -and very expensive-motorised appliances.

Rotary cutter spindles all involve problems in the provision of a suitable drive, especially when they are used in all sorts of odd locations and angles. A good deal of practical information on all kinds of drives can be found in the ME Handbook ***Milling in the Lathe,*** which covers every aspect of appliances and methods.

To be concluded