The 84 Thou Leadscrew Lathe

In The SMEE Journal of April 2011, Brian Marshall of West Sussex reported the unusual graduations on a lathe of Chinese manufacture. In particular, the leadscrew dial was graduated as 84 thou per revolution. The following may suggest the sort of circumstances which resulted in the peculiar feed arrangements.

Photo 1 shows an Astra bench mill which I purchased just over a year ago. It had been carefully reconditioned by its previous owner, Elvet Goodwin.

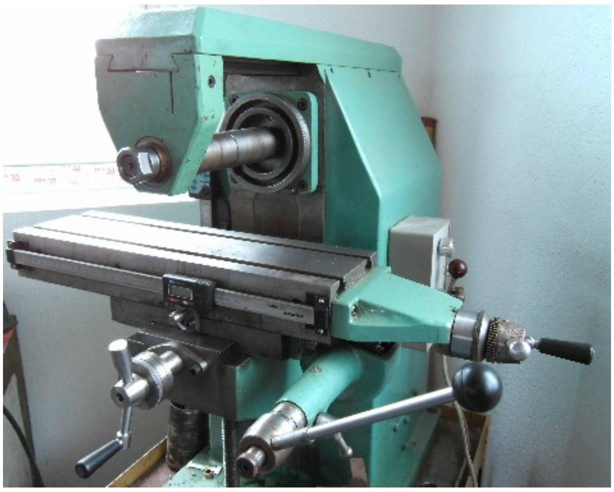

Photo 1. The Atlas bench mill showing the table feed handle. The rapid action lever is in the foreground.

Elvet had fitted a digital readout scale to the table and knee. He had also fitted a nicely graduated collar to the saddle feed. There is a collar on the table feed, but it has no graduations. I thought nothing of the absence of graduations. The digital readout obviated any requirement for them. The bench mill is first and foremost a plain horizontal milling machine. Slitting saws or side and face cutters are normally used in a straight through mode, and accurate knowledge of the table position is not essential. Elvet had separately purchased a vertical head accessory for the mill. For this he had acquired a substantial number of end mills and slot drills. When using the vertical head, both the saddle and table positions generally need to be set accurately. This had no doubt justified the addition of the digital readout scale on the table.

Recently I was casually pondering the possibility of graduating the collar on the table feed. The table appeared to move about ¼″ for each turn of the handle. To confirm this, I wound the table near to one end of its travel. Having taken up the backlash, I zeroed the DRO, and wound the handle until the table was close to the opposite end. I was surprised to discover that the table feed was not the 0.250″ per revolution I was expecting but was in fact equal to 0.2849″. I soon understood the reason.

One of the facilities on the Astra mill is a rapid action lever on the table. The lever is visible in the foreground of Photo 1. Use of the lever permits the table to be fed quickly for slitting soft materials. It also allows a "*Shaper*" type of action to be employed. The milling spindle is capable of rotating at a high speed, so a grindwheel may be mounted on an appropriate arbor and the mill used for surface grinding. All in all, the rapid action facility is quite a useful addition. The one disadvantage is that instead of having a normal leadscrew transmitting its drive through a nut, the table is fitted with a worm which engages a wormwheel on the shaft of the rapid action lever. This is seen in Photo 2.

Photo 2. A view from beneath the table showing the worm and wormwheel arrangement.

When the rapid action facility is locked, the wormwheel serves the role of the nut in a normal leadscrew arrangement. The worm feeds along, moving the table with it as the handle is turned. If the table feed handle is stationary, and the rapid action unlocked, the wormwheel acts as a pinion would against a rack, driving the worm to and fro, and with it, the table.

According to the book "*Gear Cutting Practice*" by Colvin & Stanley, at one time it was normal practice to manufacture worms and wormwheels on the basis of Circular Pitch (CP). This permitted the production of worms with convenient fractional leads. At the time of writing their book, (1937) that approach had become obsolescent and Diametral Pitch (DP) had become the norm. Interestingly, it seems that although the change to DP simplified the manufacture of wormwheels, complexity shifted to the gear ratios required for cutting the matching worms. The tables provided by Colvin & Stanley show that as many as 62 changewheels are required in order to cover the standard range of DP worm leads. The changewheels are used in sets of 4. Even with such a wide selection of changewheels, the leads obtained on the worms are only guaranteed to be the "*Closest to the desired ratio*...".

So in principle there is nothing to prevent the manufacture of a worm which has the same lead as a standard leadscrew. However, doing so would demand the use of a wormwheel with an integral CP. For example, a lead of 0.250″ corresponds to a CP of 4. Then the designer simply has to settle on a suitable number of teeth for the wormwheel. The number of teeth and the lead of the worm define the diameter of the blank to be machined. All that remains to be done is to obtain a hob with the correct profile for the chosen CP.

The DP equivalent to a CP of 4 is $4\pi = 12.56637...$, which is not a standard value, not least because any integral multiple of π is an irrational number.

It is fairly evident that a more cost effective approach is to purchase a standard DP wormwheel and worm while dispensing with the dial graduations.

In the case of the Astra mill, a DP of 11 appears to be closest to the wormwheel. This corresponds to a lead of 0.285599...″ The measured value of 0.2849″ probably reflects the approximation inherent in "*Closest to the desired ratio...*". On a plain mill such an approach is acceptable for the reasons already stated. However it is worth observing that the wormwheel does not present the same area to the worm as a nut presents to a leadscrew. Consequently wear is more likely to occur on the few wormwheel teeth which happen to be engaging the worm. The leadscrew and nut arrangement also achieves a greater averaging effect than the wormwheel, which smooths out errors in the leadscrew.

The disadvantages are of no consequence since the use of a separate scale to determine table position is preferable to relying on a leadscrew of any sort.

In the case of a lathe, a leadscrew with a peculiar pitch *might* be tolerable for plain turning. If the lathe is intended for screwcutting, it could prove difficult or impossible to achieve accurate pitches for the same reason that 62 changewheels were insufficient to achieve anything better than "*Closest to the desired ratio...*" when making worms for DP wormwheels.

If one is sufficiently determined, the advice offered by J.A. Radford in his marvellous book "*Improvements and Accessories for your Lathe*" may be adopted. It seems that the simple expedient of offsetting the tailstock and compensating by setting taper turning to the same amount, so that the tool runs parallel to the work, which one can imagine as effectively changing the length of the lathe bed, alters the effective pitch one is screwcutting. The "*Set over*" angle for the screwcutting tool is also corrected to match the taper. - Easy really!

On one view, a leadscrew of 84 thou per turn may be seen as a challenge and opportunity to learn the 84 times table. However, Mr Marshall measured the actual travel and found it to be 2.1 mm per turn. This equates to 0.082677″ in Imperial measure. So in fact, the leadscrew dial is not indicating the amount of travel one might expect. I suspect that the Chinese manufacturer used a Reduced Inch (RI) which is 1.6% shorter than the Inches with which we in the UK are familiar. There are a number of advantages to the RI. First and foremost, conversion to metric is simpler, since 1 Reduced Inch is exactly 25 mm instead of 25.4 mm which users of Imperial measure have come to expect.

I suspect that the RI principle was devised by an accountant, experienced in the techniques of misrepresenting reality.

Nevertheless, the RI system offers certain benefits to the engineer. Machining operations exhibit some advantages. Turning according to the leadscrew graduations will result in oversize outside diameters while boring operations will give undersize holes. This is beneficial in that both conditions can be cured by metal removal which is always preferable to the converse situation.

For applications demanding the utmost precision, the finished components can be placed in an oven before final inspection to bring the bores up to size or in liquid Nitrogen if it is the outside diameters which are critical. The Inspector may be obliged to wear appropriate protective clothing, but that is a minor inconvenience.

Undoubtedly, the greatest advantage of the Reduced Inch system of measure is that there are raw material savings of $(1.6\%)^3$ which is nearly 4.1% in total material costs. This translates into corresponding energy savings during production, together with lower labour costs since everything is smaller and lighter. Carriage overheads will also be less. It is hardly surprising that lathes made to the RI standard can be bought so cheaply.

The purchaser also benefits, since anything manufactured to the Reduced Inch system, being that little bit smaller, will fit into the workshop more easily.

Despite the indisputable nature of all the above advantages, I remain adamant that I will not adopt the Reduced Inch system of measure. Perhaps I am too set in my ways. Maybe I just regard the Inch and the Thou as old and trusted friends whom I have known all my life. I am not prepared to see their stature eroded in the interests of international detante, efficiency and convenience. When I purchase an Inch, I expect to be given all of it. I do not wish to receive some photo-reduced, CE marked, accountant friendly, economy version.

I am determined that my Inch SHALL remain unchanged, complete with all of its Thous, if only out of respect for the memory of my ancestors. I realise it may prove necessary to inaugurate a Campaign for Real Inches. Supporters will be given bumper stickers declaring "I LOVE MY INCH" and badges with "HANDS OFF OUR THOUS" emblazoned on them.

Brian Marshall is to be commended for unmasking this treacherous plot which strikes at the heart of Imperial Dimensional Stability. No doubt he did so despite considerable personal risk. His action of returning the *84 Thou leadscrew lathe* to the suppliers was most courageous. Brian Marshall's action is an example and inspiration to all right minded devotees of the ONLY TRUE STANDARD of measurement.

Jim Cahill