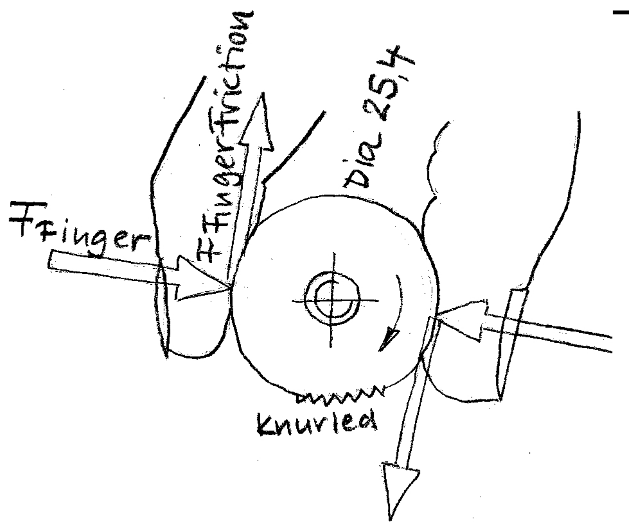
Knurling - The Mechanics Behind It

by Ulrich Viebahn
August 23th 2021

All self-built gadgets gain in appearance and usability if they are equipped with knurled knobs. A knurled knob signals an old white man that he sees an interesting thing which he can adjust and play with.
Knurled Knobs are very practical as they save the fumbling with spanners or Allen keys. More often then not, you can replace hexnuts with a threaded knob, provided that the needed clamping force (...torque) is not too high and knob diameter and grip are high enough. The finger-forces between index finger an thumb range from 50 to 70 N (200 to 300 lbf). You can check it with a (e.g.) luggage scale.



In most cases it is sufficient and cheap to put a shrunk piece of rubber tube to improve the friction coefficient of a knob - but it is ugly. Knurling has it's best effects with depths of less than 5 thousandths (increasing the diameter by 0. 25mm). Deeper penetration doesn't increase friction very much but spoils the elegance if not excuted with care.

The best material is a ductile Aluminum or steel or brass or copper.

I don't throw away the ugly chinese handles of my impulse purchases, as I can use cuts of them on the fly.

I guess that oiling improves the knurling appearance and reduces the chuck's necessary clamping force.

Even with a broad thumb you only need a knurled strip of ¼ ... ½" width. Try a knurled edge or chamfer of 1/8" .

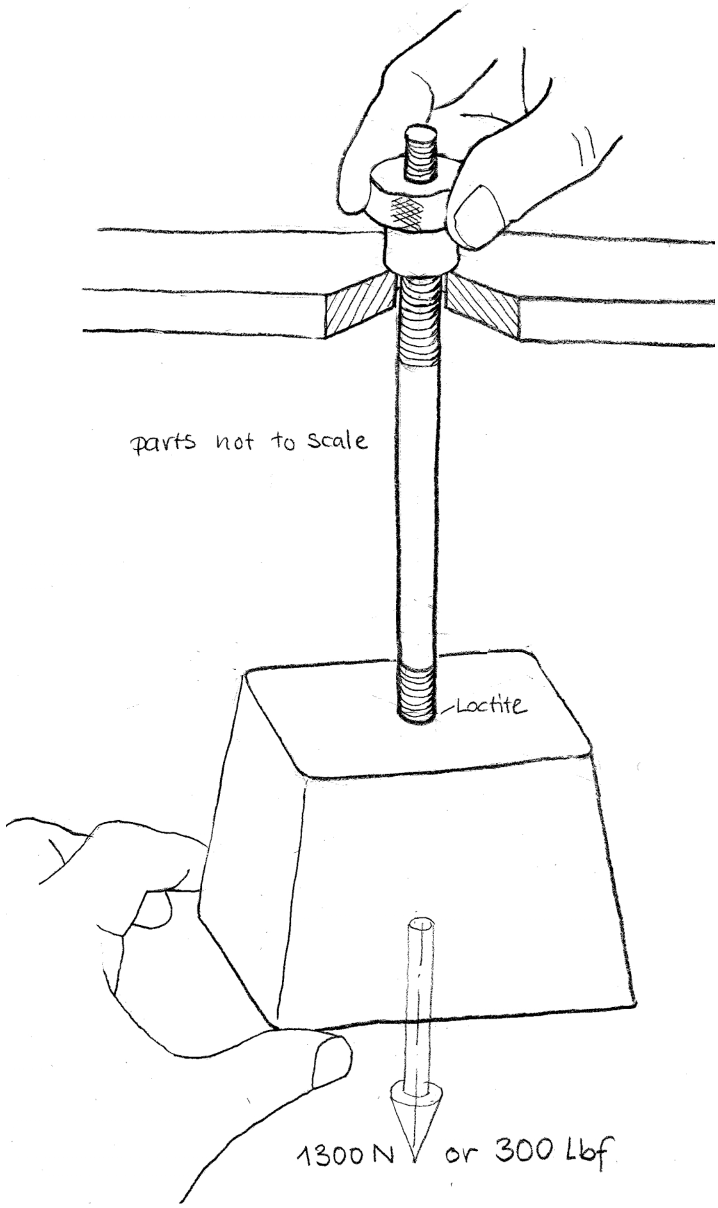
You can upgrade Allen heads by knurling them directly or by fitting a knurled aluminum or brass collar (press fit of 1 thousandth (0.01 mm) or loctite)

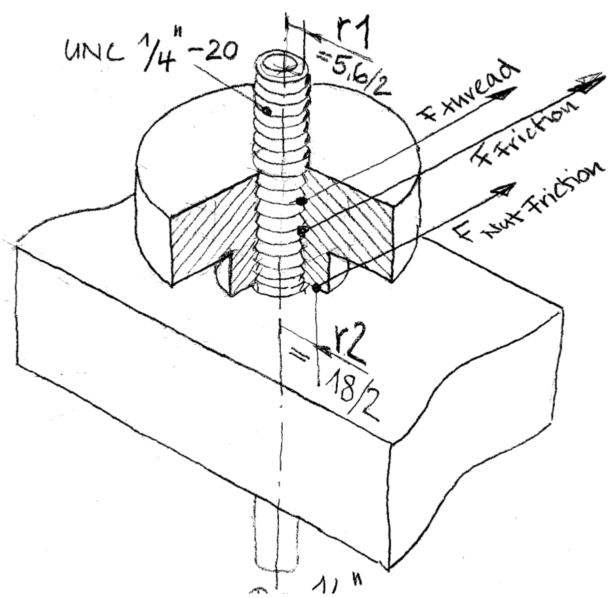
The following calculation explains why medieval thumbscrews could be operated manually by the Puritans and witchhunters.

Let’s imagine a threaded bar (UNC ¼“) and a knurled knob with a diameter of 1“ (25.4mm). Screwed on the bar and suspended is a weight with a still unknown mass.

How can we calculate the max. weight that our fingers are able to lift?

The fingers exert clamping forces onto the knurled knob which translates to a torque (force x lever). see fig. on page 1





This torque has to overcome 3 different torques in the knob / nut.
1. the lifting effect of the thread (which acts as a wedge)
2. the friction between **screw and nut** - which is much higher than we think
3. the friction between **nut and the bar** from which the mass is suspended - which is even more higher than the friction in the screw.

Force between Index and Thumb is 70 N ($\approx$ 300 lbf)
Friction Coefficient skin – knurl μ is 1
Tangential Force of 1 Finger is 70 N

resulting Torque of 2 Fingers $T = 2 \cdot 70\,N \cdot \frac{25.4}{2}\,mm = 1800\,Nmm$ (25.4 mm: knob diameter)

total Torque = torque to lift weight (screw principle)
+ torque by friction between screw and nut
+ torque by friction between nut and bar

$$= F_{weight} \cdot r1 \cdot \frac{pitch}{circumf.} \qquad F_W \cdot \frac{5.6}{2} \cdot \frac{\frac{25.4}{20}}{6.35 \cdot 3.14}$$

$$+ F_W \cdot \mu_{screw\,(oiled)} \cdot r1 \qquad F_W \cdot 0.1 \cdot \frac{5.6}{2}$$

$$+ F_W \cdot \mu_{nut\,(oiled)} \cdot r2 \qquad F_W \cdot 0.1 \cdot \frac{18}{2}$$

total Torque = $F_{weight} \cdot (\ldots\ldots)$

$$F_{weight} = \frac{\text{total Torque}}{\left(\frac{\frac{25.4}{20}}{6.35 \cdot 3.14} \cdot \frac{5.6}{2} + 0.1\,\frac{5.6}{2} + 0.1\,\frac{18}{2} \right)}$$

F_W = 1310 N or 300 lbf or 133 kg (mass)

The lifting capacity of a small knurled knob is impressive. You can double it by a knob with twice the diameter. Remember that friction eats a lot of the torque generated by your fingers. Put a tiny bit of grease onto threads and under the knob.

Most of the knurler designs I have seen at HMT (well over 100) look like heavy duty pliers. This originates perhaps in multi-spindle automatic lathes where the knurling ‚plier' must engage the turned piece from the side. This is not necessary in the paradise of bricolage. If you put the knurling wheels in the middle of the levers (principle that was used by our members *‚mark f'* and *‚ndnchf'*), then the molding of the knurling profile is easier to adjust because the thread of the butterfly screws is finer and the lever ratio screw / knurling wheels has shrunk to a quarter. Not to mention the inner forces of the knurling gadget which decrease correspondingly. It can be designed to be smaller and lighter.