For Best Knurling Results

1. Diameter of part being knurled should be turned to size and concentric to achieve a good knurling quality.
2. Knurl wheels must be exactly in center line with the work piece for an even knurl pattern.
3. Knurl wheels are to run freely and the knurl pin must be secured on the tool holder (the use of a carbide pin is recommended).
4. Use heavy flow of coolant to keep the knurl wheels cool and clean.
5. There are formulas to calculate depth of cut, tracking pitch and cutting parameter. Because of different material hardness, before starting production follow the instructions and with trial error the best result will be achieved.

Speed and Feeds

For in-feed knurling, the knurl should be fed toward the work gradually until contact is made with the blank. This can be completed within 5 to 25 work revolutions of the working piece.

For end-feed knurling, the feeds used with the turret vary considerably and are dependent on the pitch of the knurl, the material, the diameter of the work blank, and the hardness being knurled.

Knurling is ordinarily performed at the same speeds used as cutting operations. Use the same SFM used for high speed and cobalt tool bits to calculate speeds and feeds. However, where spindle speeds can be reduced without loss of production, it is recommended that spindle speeds be lowered as much as possible to increase knurl life.

For Best Knurling Performance

Before beginning Knurling process check:
- Diameter before knurl
- Diameter after knurl
- Knurl pitch
- Workpiece to be concentric
- Set wheels on center line of workpiece
- Use beveled edge wheels when form knurling
- Use full faced wheels when cut knurling
- Always use coolant when knurling
- The standard knurling depth is 35% of knurl circular pitch.

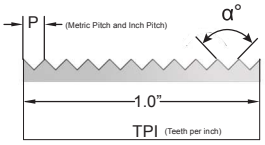
Example: Knurling Depth of 20 TPI Knurl
Circular Pitch of 20TPI is: 1.000/20=.050”
Knurling Depth is: .050” x .035% =.0175” per side

- If the knurl double tracks, the knurl wheel is not deep enough in to workpiece, increase knurling depth
- If the knurl crest rolls over, the knurl wheel is to deep in to the workpiece, decrease knurling depth
- If the knurl is not tracking, the workpiece diameter is not correct for full number of teeth, diameter must adjusted up or down by using a tracking formula.

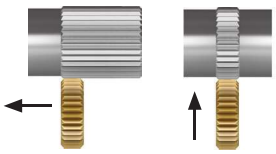
In-Feed Knurling, when the knurl wheel enter into the workpiece radially.
Once the knurl wheel has reached the depth, will take from **5 to 20** revolutions to complete the knurling operation. The revolution changes for the same size with the workpiece material hardness and knurl pitch.
End-Feed Knurling, when the knurl wheel enter into the workpiece axially.
The depth of the knurl wheel must be set before the wheel get in contact with the workpiece, the depth and pressure changes for the same size with the workpiece material hardness and knurl pitch.

Knurling Speeds and Feeds

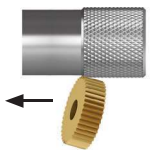
Material and Knurl Pitch



Knurl Forming



Knurl Cutting



Material Description	Material Specs	TPI	Metric Pitch	Forming Speed (SFM and V_c) Smaller ⟵ Wheel dia. ⟶ Larger	Feed rate (f_n) End Feed	Feed rate (f_n) In Feed	Cutting Speed Smaller ⟵ Wheel dia. ⟶ Larger	End Feed
Low carbon steel	1018 1117 1215	>14	>1,8	50-210 SFM [15-63 V_c m/min]	0.006" [0,15mm]	.001-.003" [,025-,075mm]	100-350 SFM [30-106 m/min]	0.009" [,23mm]
		16-20	1,6-1,2		0.008" [0,20mm]	.002-.004" [0,050-,100mm		0.011" [,28mm]
		25-35	1,0-0,7		0.010" [,25mm]	.002-.004" [,050-,100mm]		0.013" [,33mm]
		40>	0,6>		0.012" [,30mm]	.002-.004" [,050-,100mm]		0.015" [,38mm]
Alloy Steel **Tool steels**	4130 4140 D2	>14	>1,8	35-150 SFM [10-45 m/min]	0.004" [,10mm]	.001-.002" [,025-,050mm]	70-250 SFM [21-75 m/min]	0.007" [,18mm]
		16-20	1,6-1,2		0.005" [,13mm]	.001-.003" [,025-,075mm]		0.008" [,20mm]
		25-35	1,0-0,7		0.007" [,18mm]	.001-.003" [,025-,075mm]		0.010" [,25mm]
		40>	0,6>		0.009" [,23mm]	.001-.003" [,025-,075mm]		0.012" [,30mm]
Stainless Steel	304 17-4	>14	>1,8	35-150 SFM [10-45 m/min]	0.004" [,10mm]	.001-.002" [,025-,050mm]	70-250 SFM [21-75 m/min]	0.007" [,18mm]
		16-20	1,6-1,2		0.005" [,13mm]	.001-.003" [,025-,075mm]		0.008" [,20mm]
		25-35	1,0-0,7		0.007" [,18mm]	.001-.003" [,025-,075mm]		0.010" [,25mm]
		40>	0,6>		0.009" [,23mm]	.001-.003" [,025-,075mm]		0.012" [,30mm]
Aluminum **Brass** **Plastic**	6061 C360 Delrin	>14	>1,8	90-390 SFM [27-118 m/min]	0.008" [,20mm]	.002-.004" [,050-,100mm]	110-420 SFM [33-127 m/min]	0.011" [,28mm]
		16-20	1,6-1,2		0.010" [,25mm]	.003-.005" [,075-,125mm]		0.013" [,33mm]
		25-35	1,0-0,7		0.013" [,33mm]	.003-.005" [,075-,125mm]		0.016" [,40mm]
		40>	0,6>		0.017" [,43mm]	.003-.005" [,075-,125mm]		0.020" [,50mm]

Note: When knurling, start with low Cutting speed, to evaluate the wheel performance, (to avoid the premature life of the wheel) increase until optimum cutting speed and feed is achieved

Forming Knurling Versus Cutting Knurl

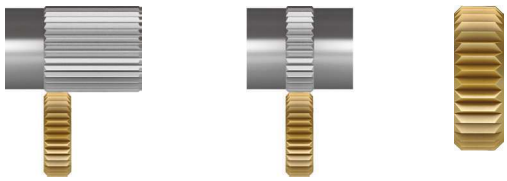
- In Forming Knurl, the knurl wheel's axis is set parallel to the workpiece axis, and forced against workpiece displacing the material to form the knurl pattern
- A large amount of pressure is required to displace the material that forms the knurl pattern, and pressure increases with workpiece diameter, pitch size and hardness
- In a large workpiece diameter, large knurl pitch, and hard material, a multi knurling pass may be required to achieve the correct knurl pattern
- For best performance and quality in Forming Knurl, when possible, a Straddle Knurling Tool is to be used, the pressure is divided within the knurl wheels over the workpiece, and pressure against the spindle of the machine is totally neutralized.
- Use beveled edge wheel when knurl forming to protect the edge from chipping and for smooth knurling surface.
- Use full face Knurled wheel when knurl cutting, the knurl wheels axis are set on negative angle, the sharp edge will cut the knurl pattern into the workpiece
- In cutting knurl, less pressure is required for the operation, higher speed and feed can be used, (use the same cutting date of High Speed or Cobalt turning tools)
- Use full faced knurl wheel when knurl cutting.

Use Forming Knurl Tool for:	Use Cutting Knurl Tool for:
- Small to medium workpiece diameter	- Medium to large workpiece diameter
- To the shoulder knurling	- For shoulderless diameter knurling
- For centerless workpiece	- For hard workpiece materials
- For band knurling application	- For long knurl application with live center
- When high surface finish required	- For higher productivity

Two Ways to Achieve Knurling

(1) Forming

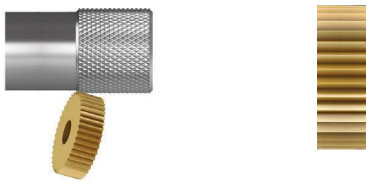
Knurl forming is achieved by pushing the knurl wheels against the blank while rotating. This will cause the material to be displaced in cold form, reproducing the same wheel pattern on the blank circumference.
The blank is increased accordingly to the Knurl Pitch. The force applied through forming is increased in larger diameters making knurling difficult and slow.



Use beveled edge wheel when knurl forming to protect the edge from chipping and for smooth knurl surface.

(2) Cutting

Knurl cutting is achieved by using knurl wheels to actually cut instead of forming the blank. The knurl wheels are set at an angle, making the knurling edges of the knurl wheels cut into the blank. Pressure is minimized while speed and feed are increased.



Use full face Knurled wheel when knurl cutting, the knurl wheels axis are set on negative angle, the sharp edge will cut the knurl pattern into the workpiece

Common Knurling Problems

Problem	Cause	Solution
Knurling double tracking	1) Knurl wheel not deep enough into the workpiece 2) The circumference of the workpiece blank is a not full multiple of the knurl pitch	1) Increase the depth of the knurl wheel into the workpiece 2) Change the blank diameter +/- .005" (.127mm) or use the tracking formula
Knurling flacking or slivered	1) Knurling a workpiece material with scaling or rough surface 2) Over-rolling the knurl wheel into the workpiece when in-feed knurling 3) Knurl Wheel too deep into the workpiece when end-feeding 4) Using 1:1 knurl to workpiece ratio	1) Turn the scaling or the rough surface of workpiece into a smooth surface 2) When in-feed knurling, reduce the depth of the knurl wheel, or reduce the number of revolutions after the knurl wheel has reached knurling depth 3) When end-feeding, reduce the depth of the knurl wheel 4) Use larger or smaller diameter wheel
Knurl destruction	1) Knurling a workpiece material with scaling or rough surface 2) Over-rolling the knurl wheel into the workpiece when in-feed knurling 3) Knurl Wheel too deep into the workpiece 4) Use of sharp full faced knurl wheel when knurl forming	1) Reduce the depth of the knurl wheel 2) Reduce the number of revolutions after the knurl wheel has reached knurling depth 3) Reduce feed and speed and improve coolant flow 4) Use beveled edge when form knurling
Knurl wheel poor life	1) Knurling a workpiece material with scaling or rough surface 2) Over-rolling the knurl wheel into the workpiece when in-feed knurling 3) Knurl Wheel too deep into the workpiece when end-feeding 4) Workpiece material too hard, or difficult to knurl (stainless steels and high temp alloys) 5) Workpiece not running concentric 6) Workpiece too hard 7) Knurl wheel not properly hardened 8) Poor lubrication 9) Not using the correct knurl wheel for the application 10) Knurl wheel not beveled	1) Turn the scaling or the rough surface of workpiece into a smooth surface 2) When in-feed knurling, reduce the depth of the knurl wheel, or reduce the number of revolutions after the knurl wheel has reached knurling depth 3) When end-feeding, reduce the depth of the knurl wheel 4) Reduce feed and speed and improve coolant flow 5) Turn workpiece concentric and into a smooth surface 6) Reduce workpiece speed 7) Change the knurl wheel 8) Improve coolant flow 9) Use beveled knurl wheel(s) when forming knurling; use full faced knurl wheel(s) for cutting knurling 10) Use a beveled knurl wheel
Uneven depth of knurl	1) Knurling a workpiece material with scaling or rough surface 2) Workpiece not running concentric 3) Using 1:1 knurl to workpiece ratio	1) Turn the scaling or the rough surface of workpiece into a smooth surface 2) Turn workpiece concentric and into a smooth surface 3) Use larger or smaller diameter wheel
Twisted knurl pattern	1) Knurl wheel not deep enough into the workpiece 2) The circumference of the workpiece blank is not a full multiple of the knurl pitch	1) Increase the depth of the knurl wheel 2) Change the blank diameter +/- .005" (.127mm) or use the tracking formula
Uneven Knurl Pattern	1) Knurl wheels are not in centerline of the workpiece	1) For a symmetric and even knurl pattern on the workpiece, the knurl wheels must to be set on centerline properly