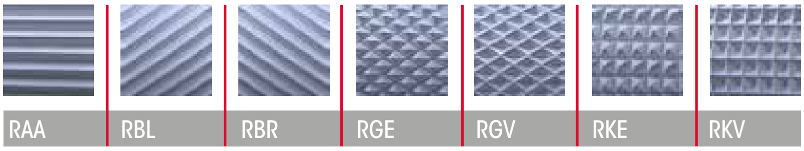
Technology

Process characteristics

Form knurling

Knurl profiles on
DIN 82 **workpiece**



Application:

- Non-cutting forming
- Processing of workpieces suitable for cold forming
- All knurling forms and profiles can be manufactured
- Suitable for face and knurling within a bore
- Knurling up to a shoulder is possible
- Tool can be started at any location on the workpiece

Handling:

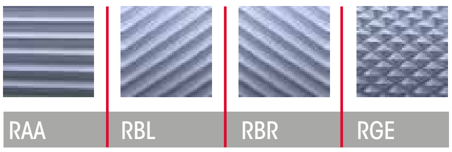
- Only minimal preparation of workpiece required
- Very easy handling of tool (short setup times)

Features:

- Material displacement increases the outer diameter of the workpiece
- The surface is compacted
- Form knurling of small diameters is possible only to a limited extent

Cut knurling

Knurl profiles on
DIN 82 **workpiece**



Application:

- Alternative cutting process
- Material removal at axial feed drive
- Machining of thin-walled, soft and hard-to-machine materials is possible
- Only cylindrical workpieces can be machined in axial direction
- Machining of small diameters is possible
- Maximum precision and surface quality, therefore suitable primarily for visible knurling
- A plunge cut is necessary for applying the tool in the middle area of the workpiece
- Knurling up to a shoulder is not possible

Handling:

- Requires precise tool adjustment and fine adjustment
- Requires precise preparation of the workpiece

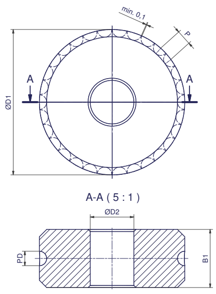
Features:

- Minimal change in the outer diameter
- Minimal surface compaction
- Lower strain on machine than in form knurling
- Minimum pressure on the workpiece and machine

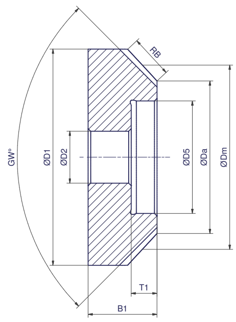
Wheel geometries

Designation	Abbreviation
Outer diameter	D1
Bore diameter	D2
Width	B1
Pitch	p
Stepped diameter	D3
Stepped diameter	D4
Collar stud bore diameter	D5
Radius	R
Total angle	GW

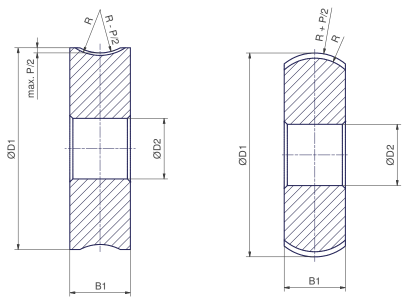
Designation	Abbreviation
Smallest diameter	Da
Average diameter	Dm
Bore depth	T1
Step width	B2
Step width	B3
Knurl width	RB
Knurl width + chamfer	RBF
Pearl diameter	PD



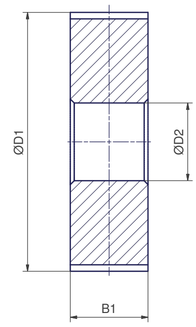
Bead knurl – No. 60



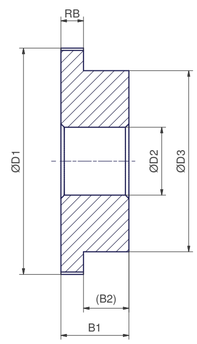
Conical knurling wheels – No. 70



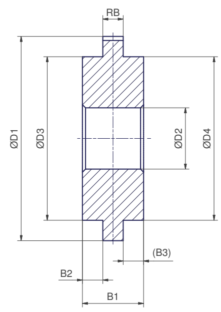
Concave/convex knurling wheels – No. 80



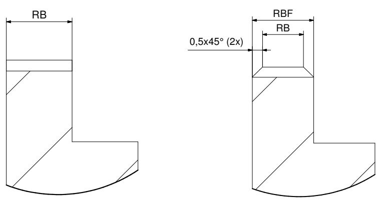
Special knurling wheels – No. 90



Special knurling wheels – No. 92



Special knurling wheels – No. 93



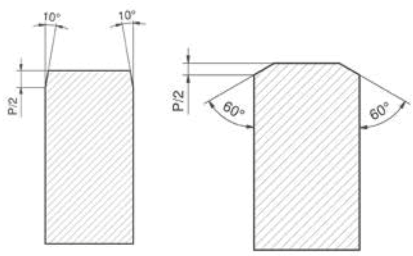
Knurl width and chamfer

The knurl width (=RB) on the knurling wheel is always defined without the chamfer.

The knurl width on the workpiece is defined by the knurl width + chamfer (=RBF) on the knurling wheel.

With 10° chamfer
– No. 17/18

With 60° chamfer
– No. 94/95



Conversion to inches

Knurling based on CP (TPI) and DP

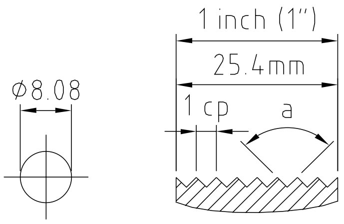
■ CP (TPI) = Circular Pitch (Teeth Per Inch)

This standard specifies the number of teeth over a distance of 1 inch (1~25.4 mm). To calculate the pitch, divide 1 inch by the number of teeth. The profile angle is defined as 70° or 90°, depending on the number of teeth per inch.

Conversion example:

Specification CP (TPI) = 20

Pitch (mm) =
1 inch (~25.4 mm) : 20 (number of teeth) = 1.27 mm



a = flank angle

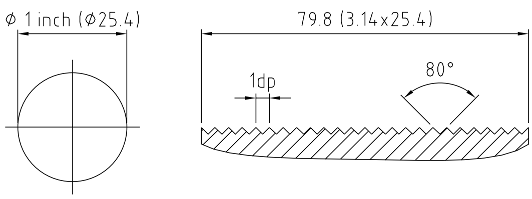
■ DP = Diametral Pitch

As opposed to CP (TPI) this standard specifies the number of teeth on the circumference of a circle with a diameter of 1 inch (1"~25.4 mm).
To calculate the pitch, divide the circumference of a 1 inch circle by the number of teeth.
The profile angle is defined as 80°.

Conversion example:

Specification DP = 64

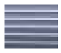
Pitch (mm) =
1 inch (~25.4) x π (3.14...) : 64 (number of teeth) = 1.25 mm



Material displacement – non-cutting forming

Our empirical values for enlargement of the workpiece diameter

Knurling profile acc. to DIN 82: RAA (knurling profile on workpiece)
Knurling wheels according to DIN 403: AA (knurling profile on knurling wheel)


RAA

Pitch [mm]		0.3	0.4	0.5	0.6	0.7	0.8	1.0	1.2	1.5	1.6	2.0
Material	Workpiece Ø [mm]	Enlargement of workpiece diameter in mm										
Free-cutting steel	5	0.08	0.14	0.18	0.22	0.27	0.29	0.35	0.50	–	–	–
	15	0.08	0.14	0.18	0.23	0.30	0.40	0.44	0.50	0.60	0.65	0.70
	25	0.08	0.15	0.23	0.24	0.28	0.35	0.44	0.53	0.62	0.70	0.98
Stainless steel	5	0.10	0.15	0.20	0.25	0.28	0.30	0.42	0.41	–	–	–
	15	0.10	0.15	0.19	0.25	0.30	0.34	0.45	0.51	0.60	–	–
	25	0.10	0.14	0.20	0.26	0.31	0.33	0.43	0.50	0.62	–	–
Brass	5	0.08	0.12	0.18	0.20	0.21	0.22	0.25	0.28	–	–	–
	15	0.10	0.14	0.20	0.26	0.28	0.29	0.35	0.41	0.44	0.48	0.55
	25	0.10	0.15	0.20	0.25	0.28	0.30	0.36	0.43	0.46	0.50	0.53
Aluminium	5	0.09	0.15	0.19	0.23	0.28	0.30	0.41	0.40	–	–	–
	15	0.10	0.15	0.19	0.26	0.29	0.33	0.45	0.51	0.57	0.65	–
	25	0.09	0.15	0.19	0.26	0.29	0.32	0.45	0.52	0.59	0.65	0.75

Knurling profile acc. to DIN 82: RBL30°/ RBR30° (knurling profile on workpiece)
Knurling wheels according to DIN 403: BR30°/ BL30° (knurling profile on knurling wheel)


RBL30°


RBR30°

Pitch [mm]		0.3	0.4	0.5	0.6	0.7	0.8	1.0	1.2	1.5	1.6	2.0
Material	Workpiece Ø [mm]	Enlargement of workpiece diameter in mm										
Free-cutting steel	5	0.11	0.15	0.20	0.24	0.28	0.34	0.45	0.55	–	–	–
	15	0.11	0.15	0.22	0.26	0.30	0.35	0.45	0.52	0.67	0.73	0.85
	25	0.11	0.14	0.23	0.25	0.28	0.36	0.45	0.56	0.70	0.72	0.90
Stainless steel	5	0.09	0.14	0.19	0.25	0.31	0.34	0.45	0.52	–	–	–
	15	0.12	0.20	0.23	0.31	0.35	0.40	0.51	0.62	0.66	0.73	0.97
	25	0.12	0.18	0.24	0.27	0.37	0.39	0.49	0.59	0.80	0.84	0.96
Brass	5	0.10	0.14	0.20	0.23	0.24	0.28	0.33	0.37	–	–	–
	15	0.10	0.15	0.21	0.23	0.24	0.31	0.41	0.47	0.53	0.55	0.63
	25	0.11	0.15	0.22	0.22	0.25	0.30	0.40	0.45	0.55	0.61	0.68
Aluminium	5	0.12	0.14	0.21	0.24	0.29	0.34	0.41	0.51	–	–	–
	15	0.12	0.18	0.23	0.26	0.36	0.40	0.50	0.56	0.56	0.61	0.75
	25	0.12	0.18	0.25	0.28	0.37	0.39	0.50	0.58	0.77	0.82	0.96

Knurling profile acc. to DIN 82: RGE30° (knurling profile on workpiece)
Knurling wheels according to DIN 403: BR30°/ BL30° (knurling profile on knurling wheel)


RGE30°

Pitch [mm]		0.3	0.4	0.5	0.6	0.7	0.8	1.0	1.2	1.5	1.6	2.0
Material	Workpiece Ø [mm]	Enlargement of workpiece diameter in mm										
Free-cutting steel	5	0.12	0.16	0.20	0.25	0.33	0.41	0.55	0.65	–	–	–
	15	0.13	0.22	0.30	0.32	0.35	0.41	0.52	0.62	0.67	0.81	0.95
	25	0.12	0.18	0.28	0.32	0.35	0.38	0.55	0.67	0.77	0.87	0.98
Stainless steel	5	0.11	0.20	0.25	0.30	0.36	0.39	0.55	0.55	–	–	–
	15	0.10	0.14	0.21	0.24	0.29	0.34	0.43	0.53	0.66	0.72	0.88
	25	0.11	0.13	0.20	0.25	0.28	0.32	0.44	0.52	0.67	0.70	0.83
Brass	5	0.12	0.13	0.16	0.20	0.24	0.28	0.32	0.38	–	–	–
	15	0.12	0.16	0.18	0.24	0.28	0.30	0.39	0.40	0.48	0.52	0.63
	25	0.12	0.17	0.22	0.23	0.27	0.30	0.38	0.41	0.48	0.50	0.63
Aluminium	5	0.10	0.15	0.21	0.25	0.33	0.36	0.50	0.57	–	–	–
	15	0.11	0.14	0.20	0.25	0.28	0.33	0.43	0.54	0.67	0.71	0.89
	25	0.11	0.15	0.22	0.25	0.29	0.34	0.44	0.53	0.68	0.69	0.88

Important notice:

This information represents empirical values. Deviations are possible.

Reference values for cutting speed and feed rate

Form knurling – non-cutting process

Material	Workpiece Ø [mm]	Knurling wheel Ø [mm]	Vc [m/min]		f [mm/U] Radial		f [mm/U] Axial Pitch [mm]			
			from	to	from	to	> 0.3 < 0.5	> 0.5 < 1.0	> 1.0 < 1.5	> 1.5 < 2.0
Free-cutting steel	< 10	10/15	20	50	0.04	0.08	0,14	0.09	0.06	0.05
	10 - 40	15/20	25	55	0.05	0.10	0.20	0.13	0.10	0.07
	40 - 100	20/25	30	60	0.05	0.10	0.25	0.18	0.12	0.08
	100 - 250	20/25	30	60	0.05	0.10	0.30	0.20	0.13	0.09
	> 250	25	30	60	0.05	0.10	0.32	0.21	0.14	0.10
Stainless steel	< 10	10/15	15	40	0.04	0.08	0.12	0.08	0.05	0.04
	10 - 40	15/20	20	50	0.05	0.10	0.17	0.11	0.09	0.06
	40 - 100	20/25	25	50	0.05	0.10	0.21	0.15	0.10	0.07
	100 - 250	20/25	25	50	0.05	0.10	0.26	0.17	0.11	0.08
	> 250	25	25	50	0.05	0.10	0.27	0.18	0.12	0.09
Brass	< 10	10/15	30	75	0.04	0.08	0.15	0.09	0.06	0.05
	10 - 40	15/20	40	85	0.05	0.10	0.21	0.14	0.11	0.07
	40 - 100	20/25	45	90	0.05	0.10	0.26	0.19	0.13	0.08
	100 - 250	20/25	45	90	0.05	0.10	0.32	0.21	0.14	0.09
	> 250	25	45	90	0.05	0.10	0.34	0.22	0.15	0.11
Aluminium	< 10	10/15	25	60	0.04	0.08	0.18	0.11	0.08	0.06
	10 - 40	15/20	30	65	0.05	0.10	0.25	0.16	0.13	0.09
	40 - 100	20/25	35	70	0.05	0.10	0.31	0.23	0.15	0.10
	100 - 250	20/25	35	70	0.05	0.10	0.38	0.25	0.16	0.11
	> 250	25	35	70	0.05	0.10	0.40	0.26	0.18	0.13

Cut knurling – cutting process

Material	Workpiece Ø [mm]	Knurling wheel Ø [mm]	Vc [m/min]		f [mm/U] Radial		f [mm/U] Axial Pitch [mm]			
			from	to	from	to	> 0.3 < 0.5	> 0.5 < 1.0	> 1.0 < 1.5	> 1.5 < 2.0
Free-cutting steel	< 10	10/15	40	70	0.04	0.08	0.20	0.13	0.08	0.07
	10 - 40	15/25	50	90	0.05	0.10	0.28	0.18	0.14	0.10
	40 - 100	25/32/42	65	110	0.05	0.10	0.35	0.25	0.17	0.11
	100 - 250	25/32/42	65	110	0.05	0.10	0.42	0.28	0.18	0.13
	> 250	32/42	80	100	0.05	0.10	0.45	0.29	0.20	0.14
Stainless steel	< 10	10/15	22	40	0.04	0.08	0.14	0.09	0.06	0.05
	10 - 40	15/25	30	50	0.05	0.10	0.20	0.13	0.10	0.07
	40 - 100	25/32/42	35	60	0.05	0.10	0.25	0.18	0.12	0.08
	100 - 250	25/32/42	35	60	0.05	0.10	0.29	0.20	0.13	0.09
	> 250	32/42	45	55	0.05	0.10	0.31	0.21	0.14	0.10
Brass	< 10	10/15	55	100	0.04	0.08	0.22	0.14	0.09	0.08
	10 - 40	15/25	70	125	0.05	0.10	0.31	0.20	0.15	0.11
	40 - 100	25/32/42	90	155	0.05	0.10	0.39	0.28	0.18	0.12
	100 - 250	25/32/42	90	155	0.05	0.10	0.46	0.31	0.20	0.14
	> 250	32/42	115	140	0.05	0.10	0.49	0.32	0.22	0.15
Aluminium	< 10	10/15	70	120	0.04	0.08	0.12	0.08	0.05	0.04
	10 - 40	15/25	80	150	0.05	0.10	0.17	0.11	0.08	0.06
	40 - 100	25/32/42	110	160	0.05	0.10	0.21	0.15	0.10	0.07
	100 - 250	25/32/42	110	160	0.05	0.10	0.25	0.17	0.11	0.08
	> 250	32/42	130	150	0.05	0.10	0.27	0.18	0.12	0.08

Important notice:

This information represents reference values.
The optimal values are to be found in the application.
Ensure effective cooling/lubrication to prevent chips from being rolled into the profile and to prolong the life of the knurling wheels.

Optimization of knurling

The pitch corresponds to the workpiece circumference

In many cases the user does not notice the relationship between the pitch and the workpiece circumference, since the pitch already corresponds to the workpiece circumference.
The knurling wheel can compensate the distortion of the pitch to produce good knurling **(see Figure 1).**

The pitch does not optimally correspond to the workpiece circumference

The more unfavourable the pitch corresponds to the workpiece circumference, the more the knurling wheel has to compensate. This results in knurling of poor quality and reduces the tool life.

Effects on the knurling quality:

- **Form knurling:**
The less favourable forming process (unnecessary strain on the material) results in a rough surface and reduced tool life. The sub-optimal penetration process causes material abrasion, which is formed into the knurling profile (indistinct profile flanks). This results in distortions of the knurling profile, which are evident in flattening of the profile and rounding of the tooth crest and tooth gullet **(see Figure 2).**

- **Cut knurling:**
The sub-optimal penetration process of the knurling wheel results in indistinct profile flanks (shadowing). This results in distortions of the knurling profile, which are evident in flattening of the knurling profile and rounding of the tooth crest and tooth gullet **(see Figure 2).**

The pitch does not correspond to the work-piece circumference

This is an extreme case. The knurling wheel cannot compensate the unfavourable relationship between the pitch and the workpiece circumference, or the profile is heavily distorted.

In the worst case this can result in "double knurling". The knurling wheel then no longer engages in the knurling profile after one workpiece rotation, but instead engages between the profile.

This is evident in the finer pitch of the knurling **(see Figure 3).**

Figure 1:
Optimal knurling profile

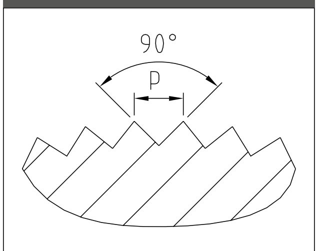


Figure 2:
Distorted knurling profile

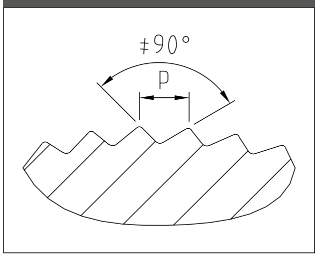
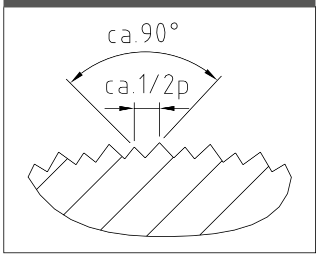
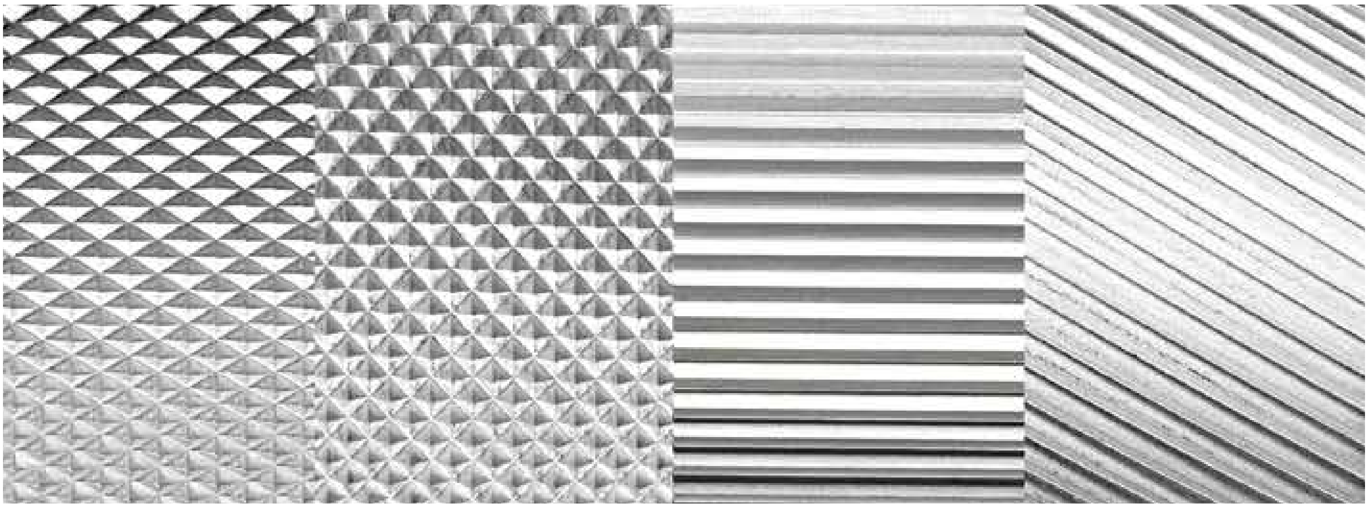


Figure 3:
Double knurling



p = pitch

Optimization of knurling



The knurling quality and the tool life can be improved substantially by optimising the knurling by changing the rough-turn diameter and/or the pitch.

The following procedure ensures systematic optimisation:

- **Correction of the rough-turn diameter until optimal knurling is achieved.**

Note:

Changing the rough-turn diameter by only a few hundredths of a millimetre has a substantial effect on the circumference {factor π (x 3.14...)} and can change the knurling quality significantly.

If a correction is not possible (tolerances cannot be maintained; workpiece diameter should not be turned), then:

- **Check whether the pitch can be changed.**

If it is not possible to change the pitch, it is necessary to manufacture a special knurling wheel with optimised pitch (defined number of teeth/outer diameter of knurling wheel).

Consultation is provided by the Hommel+Keller application engineer on the basis of a workpiece drawing and information about the machine.

The calculation of the optimal pitch is conducted on the basis of approximate formulas. Due to influencing factors (such as differences in materials) further optimisation may be necessary.

Summary:

Customer requirements:

- Clear, distinct knurling profile
- Fully formed teeth
- No double knurling/no incomplete knurling

Solutions:

1) Optimisation measures by user:

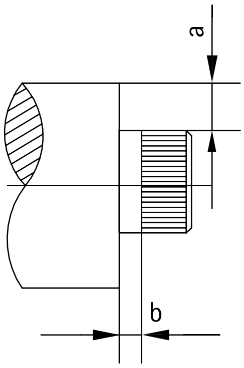
- Correction of the rough-turn diameter
- Change of the pitch

2) Optimisation measures by Hommel+Keller:

- Optimisation by manufacturing a special knurling wheel:
- Calculation of the number of teeth allows development of a knurling wheel that is specially designed for the application based on the optimal relationship between the diameter and the number of teeth.

Influencing factors

Clearance dimensions/plunge cut for cut knurling



Clearance dimension for cut knurling – workpiece collar

Due to the design-related inclination (30°) of the knurling head and the overhang of the cover plate, knurling up to a collar is not possible with a cut knurling tool.

Dimension a corresponds to the increase in the step (mm).
Dimension b corresponds to the minimum clearance for the respective knurling wheel (Ø specified in mm).

Dimension a is calculated with shoulder-height and 1/2 pitsch with a flank angle of 90°.

Dimension "a" [mm]	b 10 x 3 x 6 mm	b 15 x 4 x 8 mm	b 25 x 6 x 8 mm	b 42 x 13 x 16 mm
1	1.3	1.5	2	3
3	2.7	4.2	3.2	5
5	3	4.9	4.5	7
7	3	5.2	5.5	9
10	3	5.2	6.7	12
12	3	5.2	7	12

Dimension a = shoulder-height + 1/2 pitsch (flank angle 90°)

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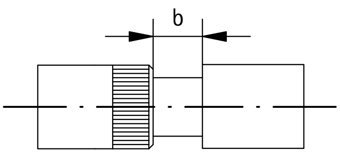

Minimum width of the plunge cut – cut knurling

If knurling is to be applied in the middle of the workpiece, a "knurling undercut" is needed (the knurling wheel requires a chamfer for centring).
Depth of the plunge cut: at least 1/2 pitch + 0.3 mm.

Dimension Knurling wheels [mm]	10 x 3 x 6 mm	15 x 4 x 8 mm	25 x 6 x 8 mm	42 x 13 x 16 mm
Minimum width of plunge (b)	3 mm	4 mm	6.5 mm	14 mm

Influencing factors

Factors affecting quality and process reliability during knurling

Numerous factors must be taken into account and optimised in order to manufacture a high-quality and functional knurling profile.

The factors listed below are crucial for process reliability, quality, precision and surface quality and should be taken into account in order to optimise the application.

- Tool properties
  - **Quality and specification of the knurling wheel**
    - Knurl width
    - Knurling wheel with chamfer
    - Material properties
      - Base material for the knurling wheel
      - Hardness of the knurling wheel
      - **Reworking**
        - PVD coating
        - TENIFER®
    - Precision
      - Run-out accuracy
      - Concentricity
      - **Profile properties**
        - Sharpness of tooth crest
        - Radius in tooth gullet
        - Flank angle
  - **Type of tool holder used**
    - Type of knurling process
      - **Form knurling**
        - Plunge knurling
        - Feed knurling
        - Plunge/feed knurling
      - **Cut knurling**
    - Quality and condition of the axle pin/bearing bush
    - Stability/freedom from vibration
    - Precision
- Machine properties
  - Precision
  - Stability/freedom from vibration
- Properties of the material to be machined
  - Hardness
  - Strength
  - Cutting values
    - Feed rate
    - Cutting speed
  - Plunge depth
  - Cooling/lubrication
  - Clearance angle
  - Quality of teeth
    - Rough-turn diameter
    - Pitch/number of teeth
    - Material distortion