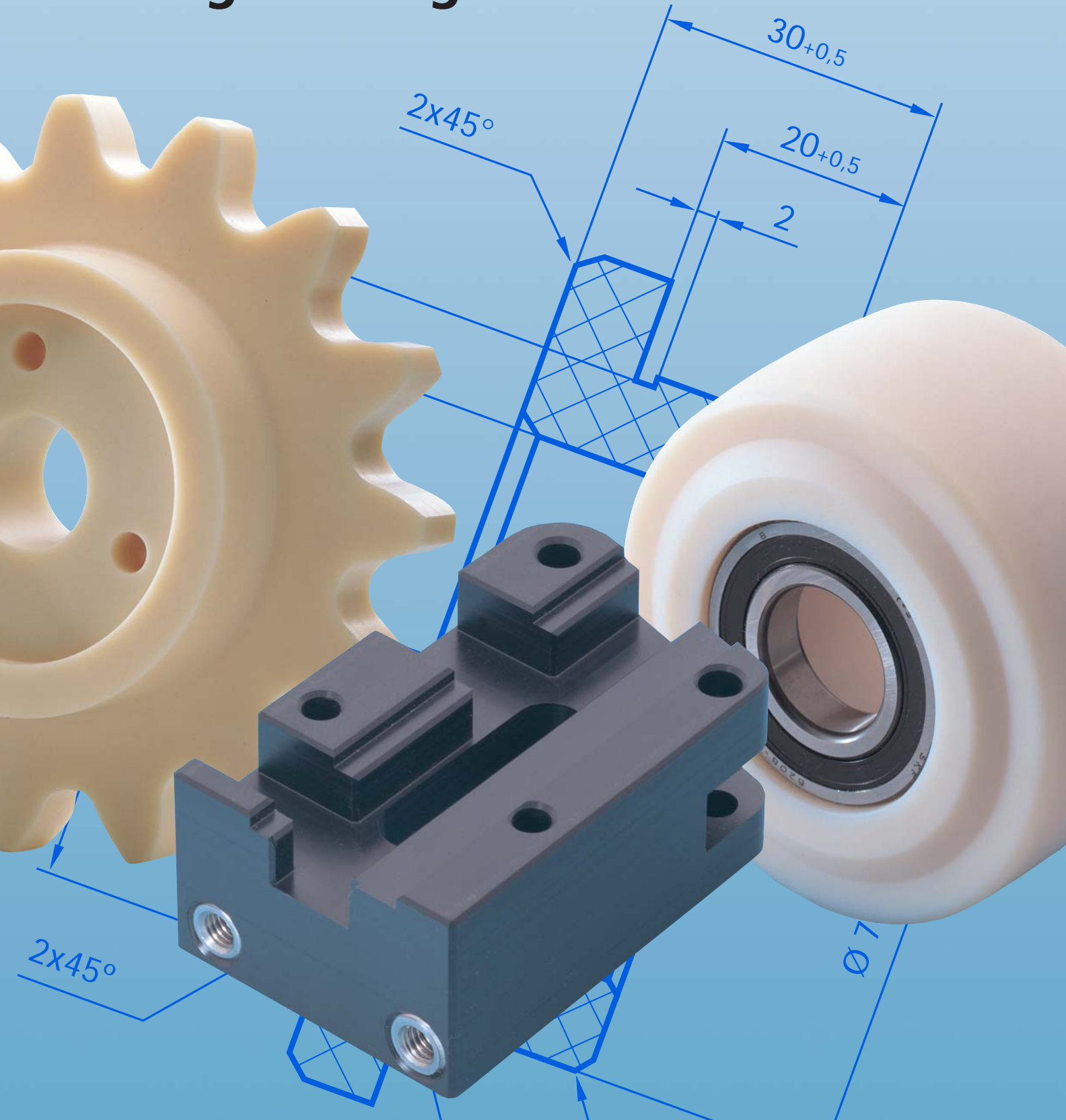
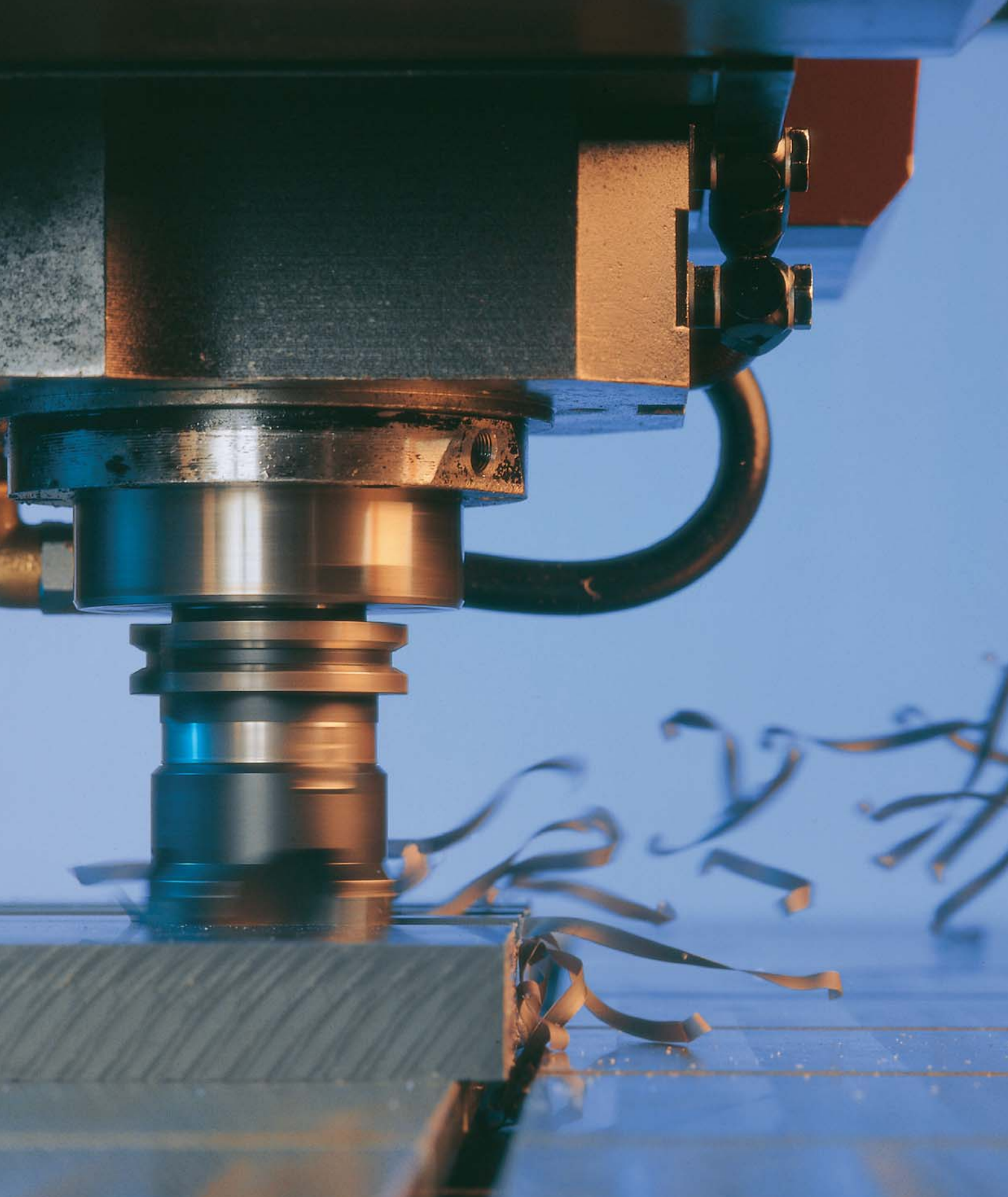




Designing with engineering Plastics





Machining guidelines

Machining guidelines

1. Machining of thermoplastics

With the increasing variety of engineering plastics and the resulting applications, design engineers now have many new horizons that were previously unthinkable with conventional materials. In many cases, in addition to material limitations, the only other limit to design possibilities are the restrictions imposed by the manufacturing process. Particularly if large volume parts are required from cast polyamides and polyacetal (POM) or polyethylene terephthalate (PET), manufacturing processes such as injection moulding cannot be used. This applies equally to complex parts that require machining from all sides with narrow tolerances.

In this area, machining has proven to be the best method. Highly precise parts and large components can be manufactured especially economically in small and medium batches by machining.

For the manufacture of high quality products, certain specific features of plastics must be considered when machines and tools are being chosen and used.

Fig. 1: Complex component made from POM



1.1 Machining equipment/tools

No special machines or processes are required for machining. The machines that are normally used in the woodworking and metal industries with HSS tools (high performance superspeed steel) or hard metal tools can be used. The only thing to consider is that when a circular saw is used to cut plastic, hard metallic saw blades must be used.

The group of glass fibre reinforced plastics is a special case. While it is possible to machine them with hard metal tools, it is very difficult to achieve economic results due to the short service life of the tools. In this case it is advisable to use diamond tipped tools, which are much more expensive than conventional tools but have a much longer service life.

1.2 Machining and clamping the workpiece

Plastics have lower thermal conductance properties than metals, as well as a lower modulus of elasticity. If not handled properly, the workpiece can become extremely warm and thermal expansion can occur. High clamping pressures and blunt tools cause deformation during machining. Dimensional and shape deviations outside the tolerance range are the consequence.

Satisfactory results are only achievable if several material-specific guidelines are considered when machining plastics.

In detail, these guidelines are:

- The highest possible cutting speed should be chosen.
- Optimum chip removal must be ensured so that the chips are not drawn in by the tool.
- The tools that are used must be very sharp. Blunt tools can cause extreme heat, which results in deformation and thermal expansion.
- The clamping pressures must not be too high as this would result in deformation of the workpiece and the clamping tool would leave marks in the workpiece.
- Because of the low degree of stiffness, the workpiece must be adequately supported on the machine table and should lie as flat as possible.

- Perfect, high-quality surfaces can only be obtained when the machines operate with low vibration.

If these guidelines are complied with, it is possible to obtain narrow, plastic-oriented tolerances with a high level of reproducibility without difficulty.

1.3 Cooling during machining

As a rule it is not absolutely necessary to cool the workpiece during machining. If cooling is to be applied it is recommended that compressed air is used. This has the advantage that in addition to the cooling effect, the chips are removed from the working area and cannot be drawn into the workpiece or tool.

Conventional drilling emulsions can also be used for cooling and are especially recommended for deep bores and cutting threads. In addition, it is possible to achieve higher rates of forward feed and consequently, shorter running times.

However, if using drilling emulsions, attention should be paid that these are completely removed after machining. This prevents oily components causing problems in subsequent processes such as bonding or painting, especially in the case of polyamides where the water in the emulsion can cause changes in the components through absorption.

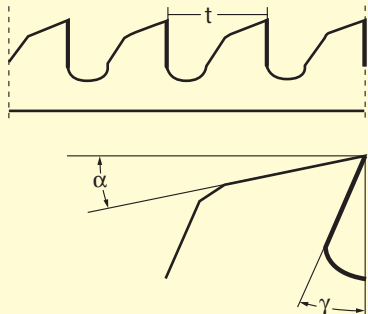
2. Parameters for the individual machining processes

2.1 Sawing

Plastics can be sawn with a band saw or a circular saw. The choice depends on the shape of the semi-finished product. The use of a band saw is particularly recommended when a “support groove” (prism) is used to cut rods and tubes and also has the advantage that the built up heat is dissipated via the long saw blade. However, the teeth of the blade must be set adequately so that the blade cannot jam.

Circular saws, on the other hand, are mainly used for cutting sheets and blocks with straight edges. Here, attention should be paid that the feed rate is adequate so that chips are removed, that the saw blade does not jam and that the plastic does not overheat at the point where it is being cut. Table 1 contains guiding values for the cutting geometry of the saw blades.

Table 1: Tool geometry for saw blades

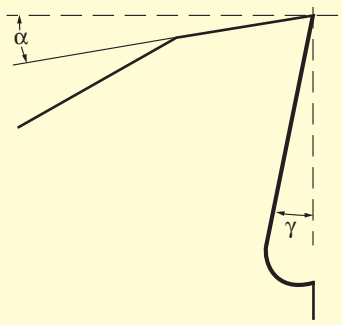


	PA, PE, POM, PET, PVDF, PVC	
	Band saw	Circular saw
α = Clearance angle (°)	30 - 40	10 - 15
γ = Effective cutting angle (°)	0 - 8	0 - 10
v = Cutting speed m/min	200 - 1000	1000 - 3500
t = Number of teeth	3 - 5 per inch	24 - 80

2.2 Milling

Milling on conventional machining centres is unproblematic. With a high cutting speed and medium feed rate it is possible to achieve high levels of machining performance with good surface quality and accuracy. In regard to the cutter geometry, we recommend the values given in Table 2.

Table 2: Tool geometry for milling cutters

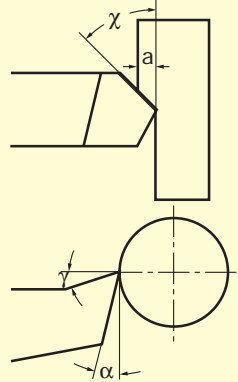


	PA, PE	PTFE	POM, PET PVDF, PVC
α = Clearance angle (°)	5 - 15	10 - 15	5 - 10
γ = Effective cutting angle (°)	0 - 15	15 - 20	0 - 10
v = Cutting speed m/min	up to 1000	up to 600	up to 1000
s_2 = Forward feed/tooth	up to 0,5	up to 0,5	up to 0,5
Angle of twist in °	0 - 40	0 - 40	0 - 40

2.3 Turning on a lathe

Since most plastics produce unbroken chips, it is important to ensure that the chips are removed, as they would otherwise catch and revolve with the part being turned on the lathe. In addition, because of the low degree of stiffness of plastics, there is a great danger of longer parts sagging, and it is thus advisable to use a steady rest. The values given in Table 3 apply to the cutter geometry.

Table 3: Tool geometry for lathe chisels



	PA, PE	PTFE	POM, PET PVDF, PVC
α = Clearance angle (°)	5 - 15	10 - 15	5 - 10
γ = Effective cutting angle (°)	0 - 10	15 - 20	0 - 5
χ = Setting angle (°)	0 - 45	0 - 45	0 - 45
v = Cutting speed m/min	200 - 500	100 - 300	200 - 500
s = Forward feed mm/rev.	0,05 - 0,5	0,05 - 0,3	0,05 - 0,5
a = Rate of cut mm	up to 15	up to 15	up to 15
The point radius should be at least 0.5mm			

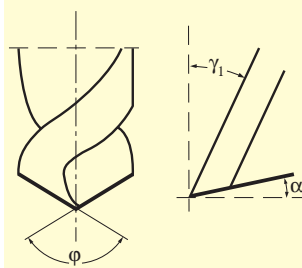
2.4 Drilling

Drill holes can be made with a conventional HSS drill. If deep holes are being drilled, it must be ensured that the chips are removed, as otherwise the plastic on the walls of the hole will heat to the point of melting and the drill will "clog". This especially applies to deep holes.

For drilled holes in thin-walled workpieces, it is advisable to choose a high drilling speed and, if applicable, a neutral (0°) effective cutting angle. This prevents the drill from sticking in the workpiece and hinders the associated stripping of the hole or the workpiece being drawn up by the drill.

Table 4 contains the recommended values for cutting edge geometry.

Table 4: Tool geometry for drills



	PA, PE	PTFE	POM, PET PVDF, PVC
α = Clearance angle (°)	10 - 15	10 - 15	5 - 10
γ' = Effective cutting angle (°)	3 - 5	3 - 5	3 - 5
φ = Point angle (°)	60 - 90	130	60 - 90
v = Cutting speed m/min	50 - 100	100 - 300	50 - 100
s = Forward feed mm/rev.	0,1 - 0,5	0,1 - 0,3	0,1 - 0,3
The angle of twist of the drill should be at least 12 - 16°			

2.5 Drilling large diameters in sections of round rod

When drilling, high temperatures build up on the cutting edges, especially with highly crystalline materials such as PA 6 G, which cannot be adequately dissipated because of the good insulation properties of the plastics. The heat causes an internal expansion in the material, which in turn causes compressive stress in the inside of the rod section. This stress can be so high that the rod tears and splits.

This can be avoided to a great extent if the material is machined correctly.

It is advisable to pre-drill the hole and complete it with a right side tool. The pre-drilled holes should not exceed 35 mm in diameter.

Drilled holes in long sections of rod must only be made from one side, as otherwise an unfavourable stress relationship is created when the drilled holes meet in the middle of the blank rod, which can lead to the rod section cracking.

In extreme cases it may be necessary to heat the blank to approx. 120 – 150°C and pre-drill it in this condition. The hole can then be completed when the rod has cooled down and when an even temperature has set in throughout the blank.

If these machining guidelines are complied with, it is quite possible to manufacture complex products from engineering plastics using machining processes even when the highest demands are placed on quality, accuracy and functionality.



Our machining capabilities:

- CNC milling machines, workpiece capacity up to max. 2000 x 1000mm
- 5-axis CNC milling machines
- CNC lathes, chucking capacity up to max. 1560 mm diameter and 2000 mm long
- Screw machine lathes up to 100mm diameter spindle swing
- CNC automatic lathes up to 100mm diameter spindle swing
- Gear cutting machines for gears starting at Module 0,5
- Profile milling (shaping and molding)
- Circular saws up to 170mm cutting thickness and 3100mm cutting length
- Four-sided planers up to 125mm thickness and 225mm width
- Thickness planers up to 230mm thickness and 1000mm width



We process:

- Polyamide
- Polyacetal
- Polyethylene terephthalate
- Polyethylene 1000
- Polyethylene 500
- Polyethylene 300
- Polypropylene
- Polyvinyl chloride (hard)
- Polyvinylidene fluoride
- Polytetrafluoroethylene
- Polyetheretherketone
- Polysulphone
- Polyether imide

- PA
- POM
- PET
- PE-UHMW
- PE-HMW
- PE-HD
- PP-H
- PVC-U
- PVDF
- PTFE
- PEEK
- PSU
- PEI

Examples of parts:

- Rope sheaves and castors
- Guide rollers
- Deflection sheaves
- Friction bearings
- Slider pads
- Guide rails
- Gear wheels
- Sprocket wheels
- Spindle nuts
- Curved feed tables
- Feed tables
- Feed screws
- Curved guides
- Metering disks
- Curved disks
- Threaded joints
- Seals
- Inspection glasses
- Valve seats
- Equipment casings
- Bobbins
- Vacuum rails/panels
- Stripper rails
- Punch supports

Information on how to use this documentation

All calculations, designs and technical details are only intended as information and advice and do not replace tests by the users in regard to the suitability of the materials for specific applications. No legally binding assurance of properties and/or results from the calculations can be deduced from this document. The material parameters stated here are not binding minimum values, rather they should be regarded as guiding values. If not otherwise stated, they were determined with standardised samples at room temperature and 50% relative humidity. The user is responsible for the decision as to which material is used for which application and for the parts manufactured from the material. Hence, we recommend that practical tests are carried out to determine the suitability before producing any parts in series.

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For further information, detailed catalogs are available:

- Information on Licharz machining capabilities of component parts
- Brochure „Material Guiding Values/chemical Resistance“
- Product information on semi-finished products of PA, POM und PET
- Delivery programme

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