Hard thread turning shortens the process chain

High-precision hard turning techniques are enjoying ever greater popularity in the metal-processing industry. High-precision hard turning is a process that shortens processing time and increases flexibility. High-precision hard turning has advantages over grinding in particular when it comes to processing complicated parts such as spindle nuts or threaded spindles in the hard state.

Figure 1) High rigidity allows higher process forces: Hembrug's turning machines are especially suitable for high-precision hard turning

Competitive machining requires constant checking and optimisation of the processes. The economic advantages of high-precision hard turning compared with grinding have been studied and discussed by several authors [1-3]. The further development of high-precision turning machines, control systems and metal-cutting tools opens up new application areas, for example thread-cutting.

Preprocessing and finishing in one chucking

The high-precision turning machines made by Hembrug in Haarlem (Netherlands) (figure 1) have hydrostatically supported work spindles and slideways. Their positioning accuracy is ± 0.1 µm, and their thermostability makes it possible to work with this accuracy for longer times. Their high rigidity allows higher process forces, so the machines are particularly well suited to high-precision hard turning.

In addition to the machine design, the application technology and the hard turning technology are constantly being further developed. An important development stage concerns the complete processing of workpieces with threaded parts. The conventional processing of these workpieces consists of the following: milling or turning in the soft state, then hardening, then grinding. The use of hard turning makes it possible to drastically shorten the process chain. Using a high-precision turning machine it is possible to carry out both preprocessing and finishing in one chucking.

The example of the manufacture of a spindle nut for a ball screw (fig. 2) demonstrates the advantages of high-precision hard turning. The main geometric data relating to the spindle nut family chosen are shown in table 1.

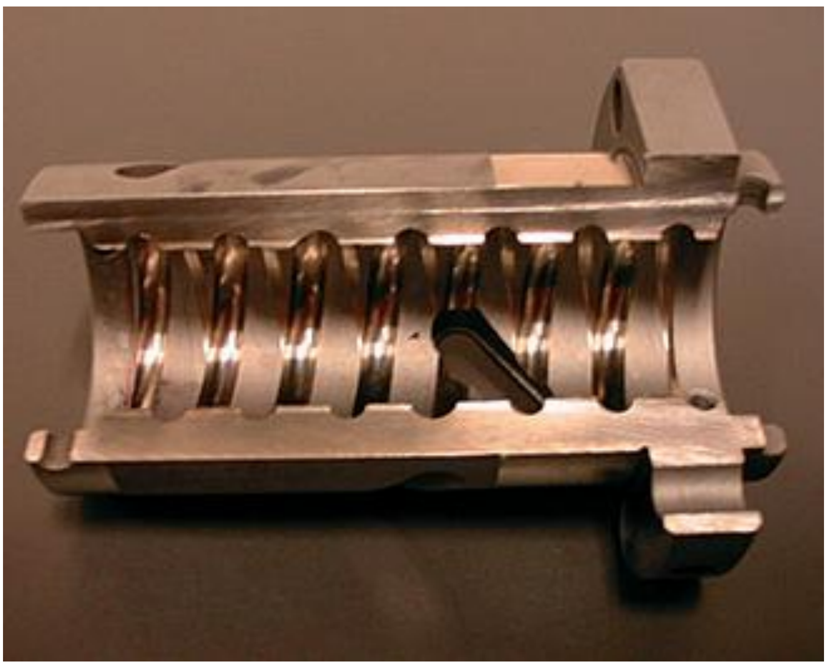
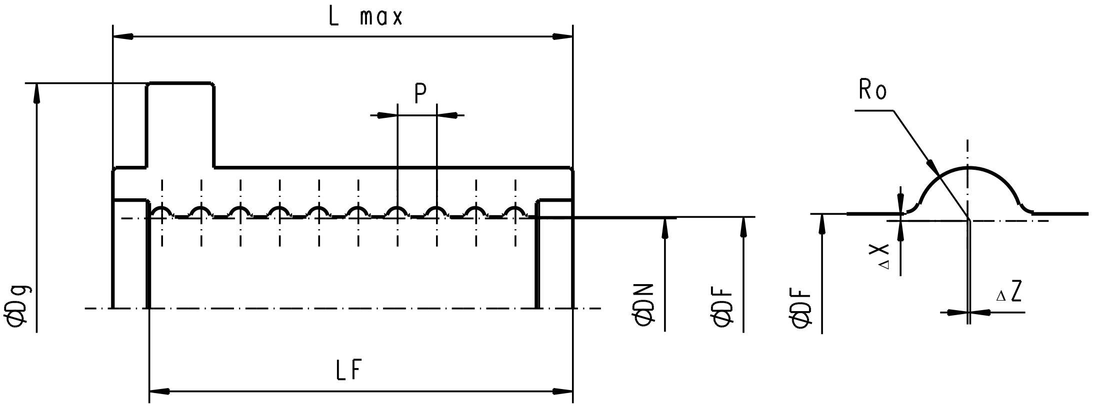


figure 2) Spindle nut for a ball screw: the economic advantages of hard thread turning are clearly demonstrated in the manufacture of this part

Geometric data relating to the spindle nut



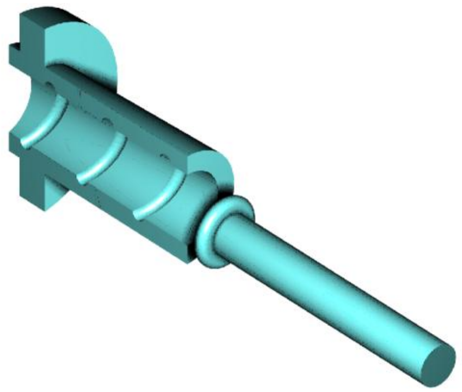
Nom. diameter	Bore diameter	Pitch	Profile radius	Displacement	Displacement	Maximum diameter	Length	Thread length
DN	DF	P	Ro	ΔX	ΔZ	Dg	L max	LF
32	32,5	5	1,89	0,352	0,095	80	82	75,5
32	32,5	6	2,143	0,370	0,105	80	92	86
32	32,5	10	3,000	0,414	0,150	80	118	107,5
32	32,83	20	3,429	0,434	0,175	85	95	95
32	32,83	32	3,429	0,434	0,175	85	100	100

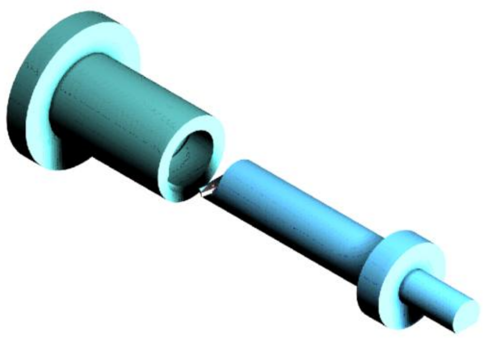
Table 1: Geometric data relating to the spindle nut

The many disadvantages of thread grinding

Thread grinding, especially internal thread grinding with an optional thread profile or a large pitch, is a very expensive process. The disc diameter and the shank diameter in the case of internal thread grinding are limited by the bore diameter, the bore length, the profile depth and the thread pitch. The large pressure angle causes high process forces. As a result, there is a high tendency to jerk. If jerking occurs, wear on the abrasive wheel, roughness and shear force increase, and the abrasive wheel has to work dynamically harder. This is generally achieved through a reduction in the cross section of the cut. This means less advance or reduced depth of cut. In the case of grinding the maximum possible cutting speed is generally set; all the measures taken to reduce jerking therefore result in a reduction in the rate of metal removal. So the rate of metal removal in the case of thread grinding is a lot lower than in the case of precision grinding.

3) Thread grinding: the rotational axis of the grinding disc is inclined to the rotational axis of the thread at the pitch angle





4) Hard thread winding: the boring bar axis and the thread axis run parallel

Fig. 3 shows the layout and geometric relations in the case of thread grinding. The grinding disc should be set according to the thread pitch so that the rotational axis of the grinding disc is inclined to the rotational axis of the thread at the pitch angle. In the case of a larger pitch angle a smaller shank diameter should be chosen. The maximum possible shank diameter for thread grinding is 18 mm in this case. The static rigidity of this shank is 8 N/µm if it is made from hard metal and 2.8 N/µm if it is made from steel. Assuming that optimum grinding conditions are achieved, the average specific cutting force will be 28 kN/mm^2. The rate of metal removal is only a low value and is between 10 and 60 mm^3/min. Because of the profiling and the dressing of the grinding disc high downtimes should be expected.

High rate of metal removal and low process forces with hard turning

In contrast to grinding it is possible with hard thread turning to find standard solutions. Using an exchangeable clamping chuck for clamping the standard indexable insert all the types of thread shown in table 1 can be turned with just one boring bar. The pitch angles can be incorporated into the clamping chuck. The boring bar axis and the thread axis run parallel. Fig 4 shows the layout and geometric relations in the case of hard thread turning.

The diameter of the boring bar is 28.5 mm if it is made from hard metal. The static rigidity reaches 50.3 N/µm, i.e. it is 6 times higher than in the case of grinding. This value makes a large cut cross-section possible for roughing (a_p = from 0.1 to 0.2 mm, f = from 0,05 to 0.1 mm) as well as optimum values for trimming. When trimming the thread profile it is possible to calculate optimum depths of cut along the thread profile corresponding to the desired roughness. The specific cutting force is from 8 to 14 kN/mm^2, i.e. it is a third or at most half of the value in the case of grinding. The maximum cutting speed is limited by the pitch and the maximum axle speed and in this example is between 60 and 150 m/min. The rate of metal removal reaches 150 mm^3/min in the case of trimming and 1,500 mm^3/min in the case of roughing. With hard turning the thread profile does not need to be preprocessed because large amounts of chips can be removed from between the thread flanks with the trimming with a high rate of metal removal. However, complete cutting of the thread in the case of hard turning is appropriate only in the case of smaller thread flanks. In theory there is no difference between hard thread turning and thread turning in the soft material state. The cut distribution differs only between processes as a smaller cut cross-section can be set with hard turning. The practical solutions differ, however, as the high accuracy requires special considerations (for example, distribution of heat effects or thermal expansion). Table 2 summarises the advantages and disadvantages of hard thread turning and thread grinding.

Table 2: Comparison of hard turning and thread grinding processes

	Hard thread turning	**Thread grinding**
Rate of metal removal	150 - 1500 mm³/min depending on advance(depth of cut) corresponding to required flank roughness	10 - 60 mm³/min depending on grinding geometry and flank geometry
Rigidity of possible tool	50.3 N/µm	0.1 - 8 N/µm depending on possible maximum shank diameter, corresponding to the disc diameter and the thread pitch
Pitch errors	0.5 - 2 µm	0.5 µm *
Roughness Ra	0.2 - 0.5 µm	0.1 - 0.4 µm *
Roughness Rz	1.5 - 4 µm	1 - 3 µm *
Accuracy Class	IT 4-5	IT 3-4 *
		* acc to bibliographical references

Limitations of the hard thread turning and thread grinding processes		
	Hard thread turning	**Thread grinding**
Flexibility	Very flexible Universal indexable insert	Low flexibility Especially disc grinding
Profile accuracy	Geometrically true, Flank accuracy in µm range	systematic internal geometric errors, depending on profiling and accurate setting, high setup costs
Surface	Higher kinematic Roughness	traces of jerking or stains from burning possible
Cutting process	Stable	tendency to jerk

Table 2: Comparison of hard turning and thread grinding processes

The boring bar for hard thread turning with a full tungsten carbide shank is much more rigid than the grinding disc shank. The universal indexable insert removes the chips with a smaller contact length, so smaller process forces occur and a much greater rate of metal removal is still achieved. It is important that the cutting edge of the tool corresponds to the generator curve (profile curve), i.e. that the tangents of the thread profile curve and of the cutting edge are identical. It is therefore possible in theory to produce geometrically true thread profiles. With thread grinding, on the other hand, the paths of the individual punches move from the grinding disc into the thread area. In this way a systematic internal geometry error occurs. Minimising the geometry error in the case of thread grinding by profiling the disc and/or by modifying the setting angle increases the processing time required for thread profile grinding.