Tvrdé struženie vs. Broušení - ekonomické aspekty

Hard Turning vs. Grinding - economical aspects

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Abstract
New production technologies are designed to improve productivity, product quality, flexibility and environmental performance of production processes of machines. Both the development of processing technologies, and above all, the new cutting tools of construction materials such as regular polycrystalline boron nitride (PCBN) and the development of the construction machine tools enable to reduce significantly costs of production. The work presents the characteristics of hard turning process, its development of trends and economical aspects. It shows the confrontation between grinding and alternative technologies in production, machines and parts of machines, for its hard turning.

Keywords
Hard turning, hard machining, polycrystalline boron nitride, development of cutting tools, economical aspects and benefits of hard turning, grinding

1. Introduction

Technology has always played an important role in development of machining industry, enabling in this way cost reduction, quality improvement of the processes and productivity increasing, flexibility and ecology. On the other hand development in machining area drives development of technology in all industry branches not only in the machine industry. Machining used to be the process dependent on operator's abilities. Nowadays CNC machine tools contribute to increasing of products quality and reduction of production costs. To the developing technologies in the machining are included: high speed cutting (HSC), high performance cutting (HPC) and hard machining (HM) which together with high speed machining (HSM) displaces electrical discharge machining (EDM) and conventional milling in the production of molds and dies.

This publication acquaints with characteristic of hard machining in particular focusing on the turning and grinding processes, confrontation of those processes which target isn't discrimination of grinding but only acquainting of new trends in machining of hardened materials and its economical aspects and benefits.

1.1 Definition of hard machining process.

Hard machining, known also as hard part machining, is a process in which a workpiece material in a hardened state approximately above 45 HRC is machined with tools of geometrically defined cutting edges. Among the aforementioned technology hard turning is gaining increasing popularity and substitutes grinding process of hardened parts of machines.

Fig. 1. *Hard turning with the CB 7015 insert. [fot. Sandvik Coromant]*

1.2 Machined materials and tools materials used in hard machining.

Mostly machined materials: hardened alloy steel (bearing steel, tool steel, high speed steel, carburized steel), hardened cast iron, sintered carbides, metal-ceramic composites.
Materials used as a tool in hard machining: cubic boron nitride (CBN), oxide ceramics (white ceramics), mixed ceramics (black ceramics), silicon nitride, polycrystalline diamond.
Polycrystalline cubic boron nitride is characterized by extraordinary hardness at elevated temperatures and compressive strength with good fracture toughness. CBN is the dominant choice for the most demanding and advanced applications, especially for the machining of parts that were previously performed in the process of grinding.

Fig. 2. *Sandvik Coromant inserts 7015 and 7025dedicated to hard machining. [fot. Sandvik Coromant]*

1.3 Example of conventional machining optimalization.

The graph on Fig. 3 presents two ways of machining a material such as shaft, bushing or disc. On the left side, there is an example of conventional machining process and on the right- an example of optimized process. As we can notice conventional process includes forming by plastic methods, forming by cutting processes (like milling, turning and drilling), next step is hardening and in the finish grinding (like preliminary, profiling and finishing grinding). Optimized process includes forming by plastic methods connected with hardening or only hardening and hard machining. As we can notice that optimized process is much shorter and enable to avoid some operations. This helps to reduce: the number of machine tools and the processes, fixed costs, time and working space. Combining the advantages of multi-task machines with software that supports the machining process, we gain a very powerful and flexible tool.

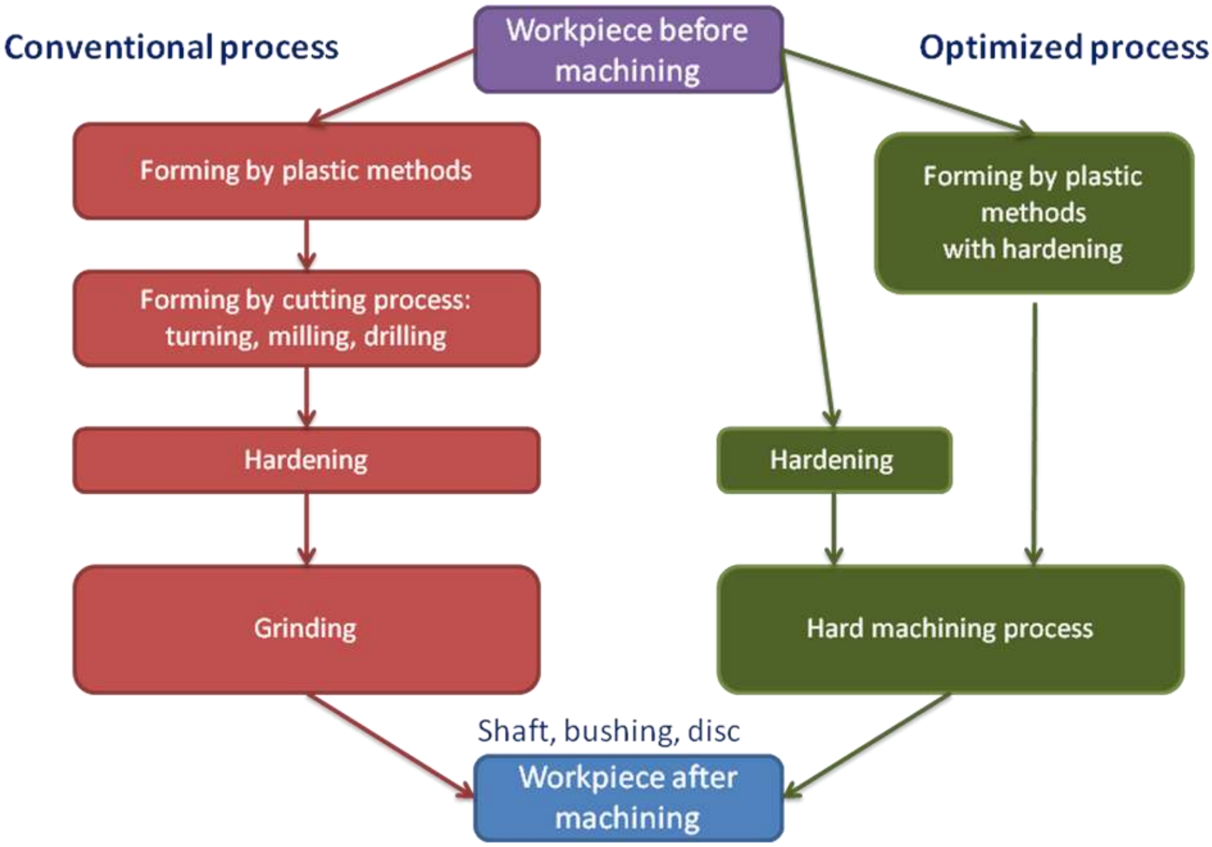

Fig. 3. Conventional and optimized machining process

1.4 Heat fluxes and methods of heat removal in the hard turning.

In machining process approximately 80% of heat should be eliminated while getting rid of chips and coolant, 10% cent should be overtaken by a tool and another 10% by a machined workpiece. In hard turning, coolant is rather rarely applicable or cold air is performed. Sometimes minimum value of oil and minimum quantity lubrication can be applied, too. Coolant should be directly applied to machining zone, not to a machined material.

Fig. 4. *Hard turning of the shaft on wet.*

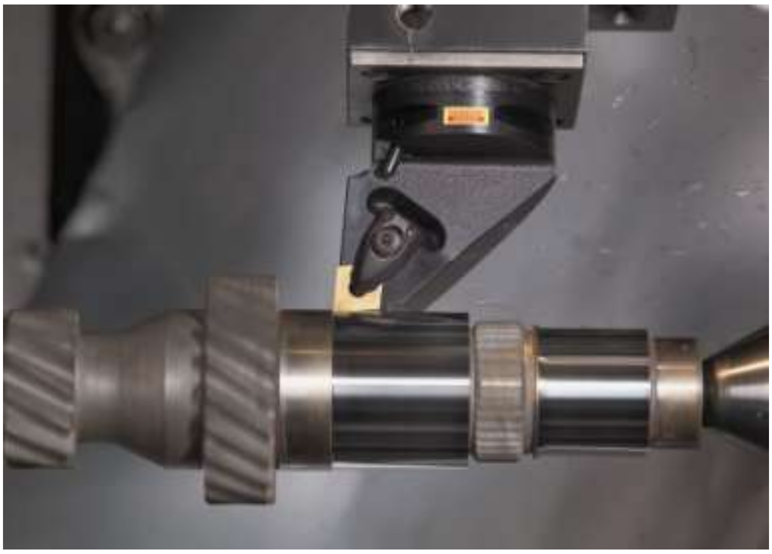

Fig. 5. *Dry cutting without coolant. [fot. Sandvik Coromant]*

1.5 Cutting tools selection.

Tolerance is a parameter which is crucial when selecting cutting tools. To achieve lower range of tolerance, cubic boron nitride inserts should be selected and in order to achieve high productivity, ceramic tiles are recommended.

Fig. 6. *Cutting tools selection*

1.6 Comparison of energetic pointers and geometric properties.

The table 1 compares the rates of energy and geometric properties on the basis of machining of hardened shaft (62 HRC), made of bearing steel 100Cr6 (ŁH15). I comparison with grinding, in the hard turning, cutting power and energy are reduced. Geometric properties of a machined surface are similar.

__Table 1.__ - Comparison of energetic pointers and geometric properties.

Factor		**Hard turning**	**Grinding**	
Tool		CBN insert	CBN grinding wheel	Al_2O_3 grinding wheel
Cutting parameters	$l_S=b_S=15$ mm d=16mm	$v_C=160$ m/min air	$v_S=58$ m/s emulsion 10%	$v_S=45$ m/s emulsion 5%
Cutting force	F_C [N] F_C' [N/mm]	$F_C=34{,}1$	F_C'=2,25	F_C'=0,44
Cutting power	P_C [W]	90	1960	297
Cutting energy	E_C [J/mm^3]	6,8	65,3	99
Surface roughness	R_Z [um]	0,5-0,7	0,7	0,4-0,5
Max. height of waveness	W_P [um]	0,8-1,1	1,1	0,7-1,1
Roundness deviation	Δ_O [um]	0,2-0,25	0,9	0,15-0,4
Circularity deviation	Δ_W [um]	0,6-0,9	1,4	0,3-1,1

1.7 Example of hard turning application in machining of pinion shaft.

Below, it is an example of optimized machining process of a pinion shaft. Only cylindrical surfaces were machined. Previous manufacturing method included roughing, finishing and groove grinding done on separate machines. New manufacturing method include machining on the 4 axis CNC lathe. Semi-finishing by means of ceramic tool. and finishing by cubic born nitride tool. In effect we have 1 CNC lathes replacing 3 grinding machines and cycle time is reduced by up to 80%.

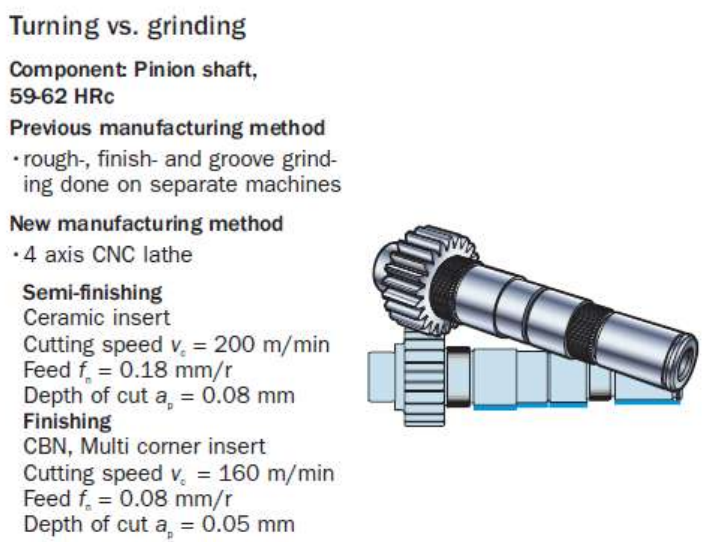

__Fig. 7.__ Turning vs. grinding in machining pinion shaft. [fot. Sandvik Coromant]

1.8 Costs estimation of grinding and hard turning processes.

The chart below shows cost estimation of grinding and hard turning processes of the same component. The chart was prepared for pinion shaft. I showed it to you in the last slide. Investment in machine, tools and floor space are comparable. However, manpower and fixed costs are much bigger for grinding process.

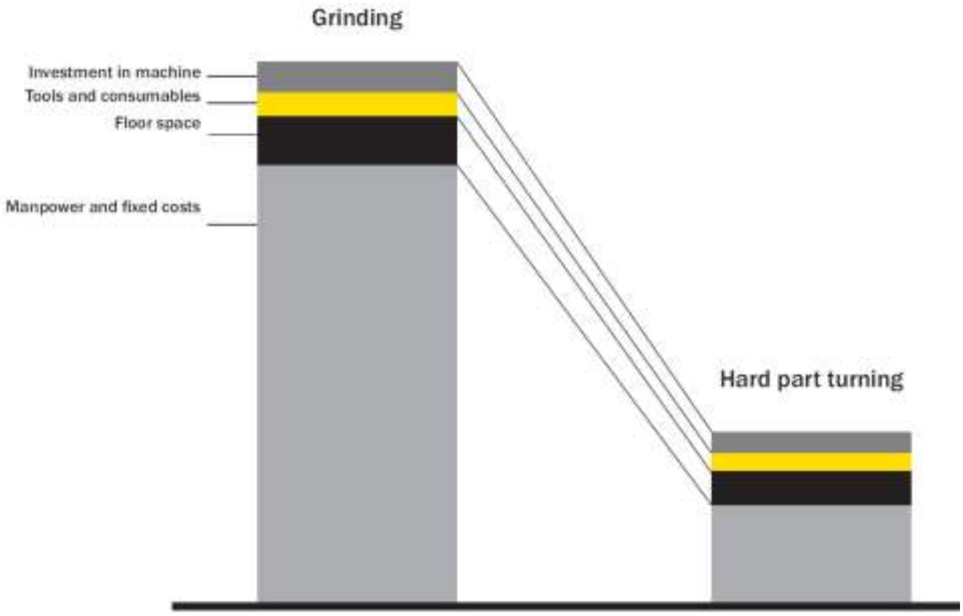

Fig. 8. *Costs estimation of grinding and hard turning processes. [fot. Sandvik Coromant]*

1.9 Comparison of grinding and hard machining.

Table 2. *- Comparison of grinding and hard turning*

Grinding		Hard turning
-	Energy consumption	+
-	Investments in machine	+
-	Multiple machining operations in one set-up	+
+	Macro- and micro geometry of machined surface layer	+
+	Physical properties of the machined surface layer	+
-	Ecological aspects of the process	+
-	Operator's safety	+
-	Marketing	+

In the table 2 there are compared the main of characteristics of grinding and hard turning.
As we can notice:

- energy consumption is much lower for hard turning,
- investments in machine and multiple machining operation in one set-up are a better for hard turning,
- macrogeometry, microgeometry and physical properties of the surface are almost the same,
- ecology of machining process is much better for hard turning. We can recycle the chips and we don't need to use coolant or we use cold air. Consumption of energy in hard machining is several times lower than in grinding process,
- lathes are safer than grinding machines for operator of machine tools,
- marketing of cutting tools is better developed.

Fig. 9. *Hard machined parts of machines. [left fot. Sandvik Coromant]*

1.10 Advantages and development of hard turning technology.

Main advantages of hard turning in comparison to grinding process are:

- high flexibility of process and multiple turning operations can be performed in just one set up
- a single point contact method
- complex shapes and profiles can be performed
- simplified kinematics of the process and a relatively small number of parameters which affect it,
- comparable to the grinding accuracy of dimensions, shape and quality machined surfaces,
- shorter technological process,
- conventional machining and hard machining can be done on the same machine tool,
- lower manpower and energy consumption of technological operations, lower space floor,
- two different strategies of machining to choose: high accuracy method and high productivity method,
- ecology of process: coolant isn't required or cold air is applicable, lubricants aren't required and chips can be easily recycled.

Greater efficiency and better economical aspects of hard turning technology can be obtained through better quality of machined surface and greater accuracy of machined workpieces, tool life increase and cutting edge stability by means of chemical composition of super hard materials and ceramics, new coating applications – multilayer nanocoating.

Development of hard turning and its economical aspects contributes to development of machine technology, development of production technology, development of materials and machining technology, tooling development, constant effort to minimize manufacturing time and production costs.

This innovative technology gives economical and qualitative benefits. At present research is conducted in the field of hard machining technology in laboratories of universities and cutting tools producers. Engine of this research is cost reduction in production metal parts of machines and improvement of machining performance and quality.

2. Conclusion

The main advantages of using hard machining are:

- high flexibility of the process,

- complex geometrical shapes of a given material can be performed,
- simplified kinematics of the process and a relatively small number of parameters which affect it (in comparison with grinding),
- comparable size and shape accuracy, comparable quality of a machined surface,
- time reduction of technological process,
- lower energy consumption,
- smaller floor space requirement,
- elimination and reduction of coolant and lubrication which make the process ecological,
- 3rd class of accuracy and Rz ~ 1um can be achieved.

Hard turning is applicable to the machining process of complex contour and profiles. The one of main advantage is possibility of cutting in one set up. Hard turning doesn't require coolant, formed chips are recycle in opposite to grinding.
Success of hard turning it isn't dependant on the on its individual elements, but on whole machine system:

- dynamic stiffness of machine tools,
- right selection of tools material,
- quality of cutting edge,
- stiffness of cutting tools and tool inserts,
- right selection of machining parameters,
- stiffness of workpiece,
- method of cheap removal and cooling system.

Please note that hard machining technology is not intended to completely exclude the grinding process in the treatment of machine parts. This technology, despite the many skeptical opinions is an alternative solution to in many cases, to significantly improve the economics of the machining process, increase productivity and shorten production time.

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