Tvrdé soustružení, obrábění alternativní k broušení vysoké tvrdosti oceli

Hard turning, machining alternative for grinding of high hardness steel

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Abstract
The struggle of conventional and new production technologies have lasted for many years. The experts from around the world are puzzled by the problems of improving productivity, product quality, flexibility and environmental performance of production processes. All of these, in order to meet the newer standards and requirements of their customers. What used to go beyond customer expectations, today have become a standard. What to do in order to satisfy still increasing expectations? The solution are innovative production technologies. One of those technologies is the processing of materials in the hardened state, and in particular the so-called hard turning. This publication presents the characteristics of process materials in the hardened state, the confrontation with grinding technology and trends.

Keywords
Hard turning, hard machining, innovative production technologies, CBN, polycrystalline cubic boron nitride, development of cutting tools, machining of high hardness steel, grinding

1. Introduction

The struggle of conventional and new production technologies have lasted for many years. The experts from around the world are puzzled by the problems of improving productivity, product quality, flexibility and environmental performance of production processes. All of these, in order to meet the newer standards and requirements of their customers. What used to go beyond customer expectations, today have become a standard. What to do in order to satisfy still increasing expectations? The solution are innovative production technologies. One of those technologies is the processing of materials in the hardened state, and in particular the so-called hard turning.

1.1 Definition of hard machining.

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 gains popularity and substitutes more often grinding process of machines' hardened parts and of course tools also.

Fig. 1. *Hard turning. [fot. Monforts]*

1.2 Machined materials and tool materials used in hard machining.

The most commonly machined materials in hardened state are:

- hardened alloy steel (bearing steel, carburized steel, tool steel: cold- and hot work steel, high speed steel),
- hardened cast iron,
- sintered carbides,
- metal-ceramic composites.

The most commonly used as a tool materials are :

- cubic boron nitrides (CBN) – fig. 2,
- oxide ceramic (white ceramic),
- mixed ceramic (black ceramic),
- sintered carbides,
- 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 the parts that were previously performed in the process of grinding.

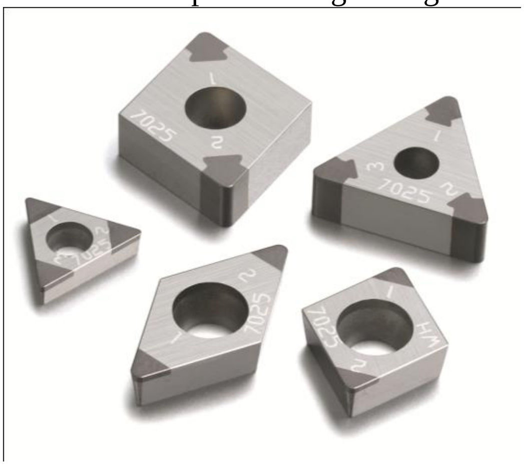

Fig. 2. *Inserts dedicated to hard machining. [fot. Sandvik Coromant]*

1.3 Example of conventional machining optimization.

The graph on fig. 3 presents two different ways of machining a material such as shaft, bushing or disc in a hardened state. 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 end 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 optimized process is much shorter and enables to avoid some operations. It helps reduce the number of machine tools and the number of 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.

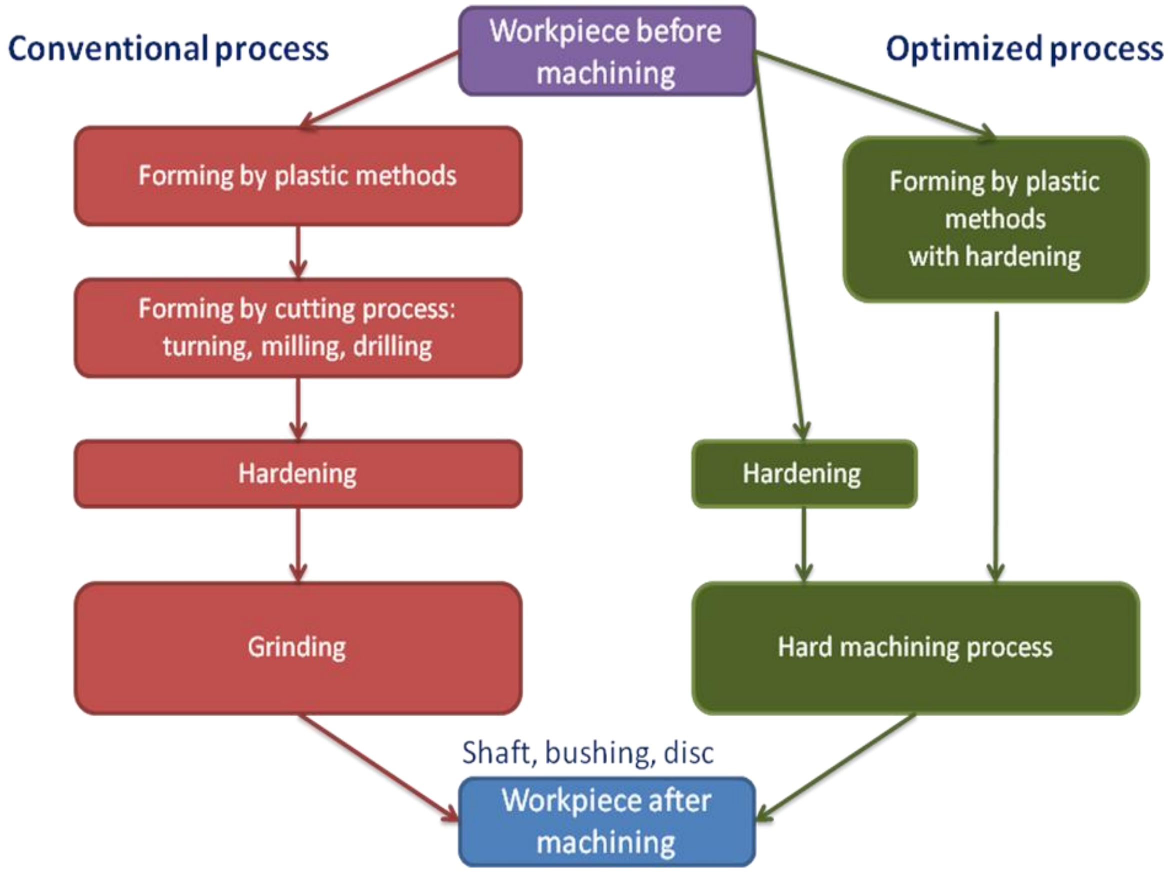

Fig. 3. *Conventional and optimized machining process*

1.4 Heat fluxes during hard turning.

In the process of hard turning 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. Tool materials are so durable that coolant is not necessary. In some cases, cold air, minimum volume of oil or minimal quantity of lubrication can be applied instead. Coolant should be directly applied to machining zone, not to a machined material.

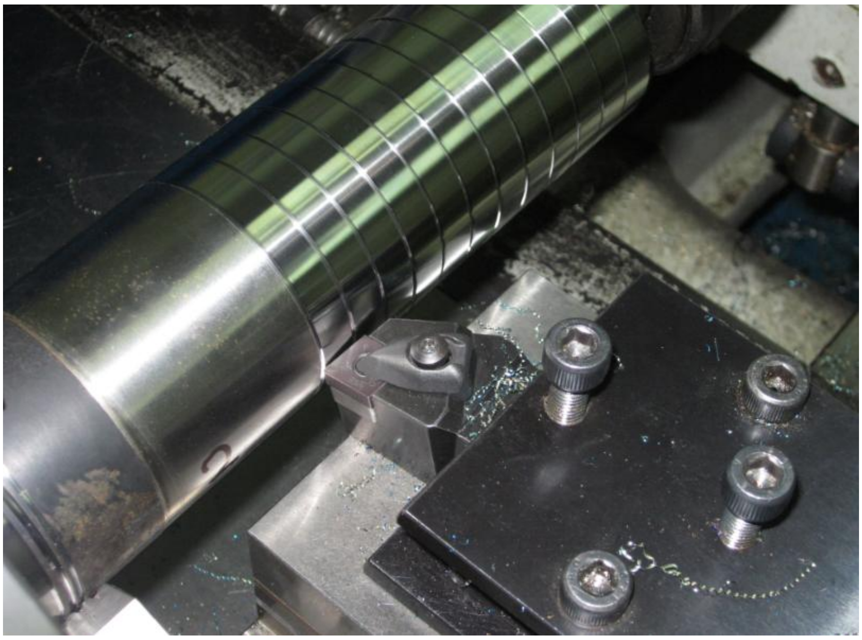

Fig. 4. *Researche on the dry cutting of tempered cold work tool steel with WNT borazon insert. [fot. Jakub Siwiec, Department of Manufacturing Tehnology, Cracow University of Technology]*

1.5 Comparison of energetic pointers and geometric properties.

As it has been mentioned at the beginning, grinding has been a typical process of machining of the hardened pieces. The table 1 presents comparison of some energetic and surface layer properties of a tempered shaft (62 HRC), made of bearing steel (100Cr6). As we can notice, cutting power and specific cutting energy are much lower for hard turning than for grinding.

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

1.6 Applications of hard turning.

In the following pictures, many-roller metal tape forming machine is shown (fig. 5). It is used for steel and aluminum profile profiles producing. In this case, hard turning is used for the machining of the rollers which are made of cold work tool steel. As you can notice each roller has different shape and dimension. The grinding process would be definitely too expensive for this application. The producers of these many-roller metal tape forming machines use a special stiffness lathe and ceramics or CBN inserts. Sometimes coolant is used because they have problems with keeping appropriate dimensions during individual production. The lifetime of inserts is shorter, but it is easier to control dimensions and tolerance which change under the influence of heat during hard turning. Sometimes, shapes of the rollers are very complicated. The other example of application of hard turning is production of punches and dies.

Fig. 5. *Many-roller metal tape forming machine. [fot. Zhongji]*

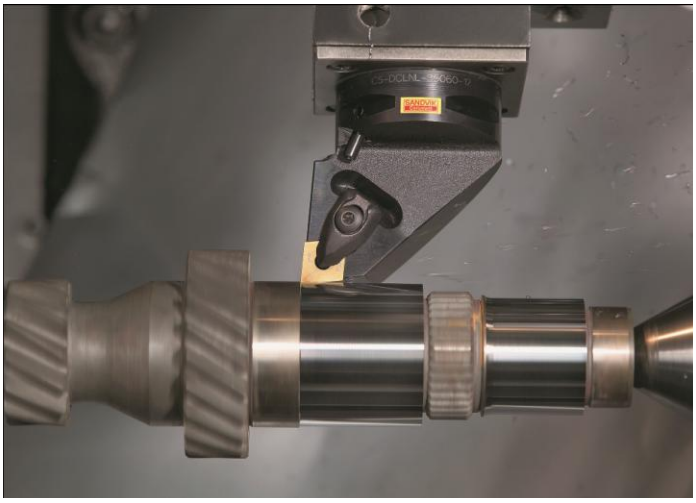

Fig. 6. *Hard turning of pinion shaft with the CBN insert. [fot. Sandvik Coromant]*

1.7 Costs estimation of grinding and hard turning processes.

Below, there it is an example of optimized machining process of a pinion shaft (59-62HRC). Only cylindrical surfaces were machined. Previous manufacturing method included roughing, finishing and groove grinding was 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 result we have received only one CNC lathe replacing three grinding machines and cycle time is reduced by up to 80%.

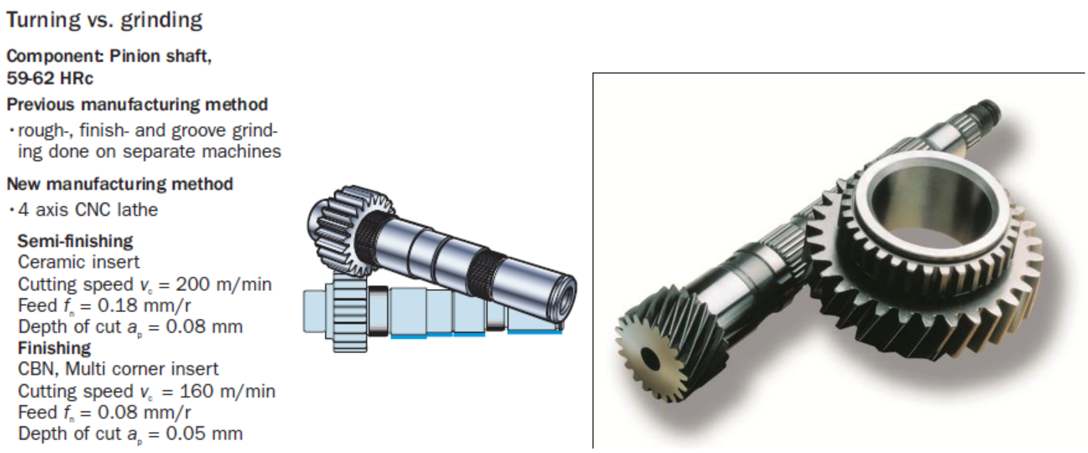

Fig. 7. *Turning vs. grinding in machining pinion shaft. [fot. Sandvik Coromant]*

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.

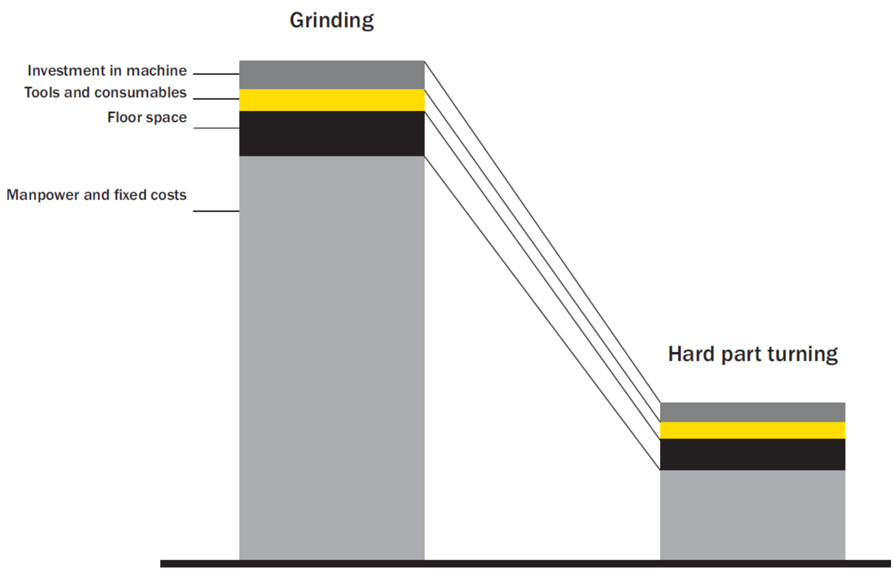

Fig. 8. *Costs estimation of grinding and hard turning processes. [fot. Sandvik Coromant]*

1.8 Grinding and hard turning - comparison.

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

Grinding	+ better, - worse	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 some important factors. As we can notice:

- energy consumption is much lower for hard turning,
- investments in machine and multiple machining operation in one set-up are better for hard turning,
- macrogeometry, microgeometry and physical properties of the surface are similar, but better quality and efficiency can be obtained through connection of hard turning connected with high precision grinding processes,
- ecology of machining process is much better for hard turning. The chips can be recycled, coolant is not necessary or cold air can be used. 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.

1.9 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 with 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 increases 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 some research is being conducted in the field of hard machining technology in laboratories of universities and among cutting tools producers. The target of this research are costs reduction during machining, improvement of machining performance and quality.

2. Conclusion

Hard turning is applicable to the machining process of complex contour and profiles. The one of main advantages is possibility of cutting in one set up. Hard turning does not require coolant, formed chips are recycle in opposite to grinding.

The success of hard turning it is not dependent on the on its individual elements, but on whole machine system:

- dynamic stiffness of machine tools and stiffness of workpiece,
- right selection of tool material,
- quality of cutting edge,
- stiffness of cutting tools and tool inserts,
- right selection of cutting parameters,
- 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 many skeptical opinions is an alternative solution to significantly improve the economics of the machining process, increase productivity and shorten production time.

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