5.5 HIGH SPEED CUTTING MACHINES

Technology and machines determined for high speed chip machining became the important part of the manufacturing basis in many industrial enterprises. It is not only by chance that they find their utilization in the special manufacturing types, especially in the aircraft, automobile and medicine branches and in the manufacture of tools and moulds. High speed cutting is already the irreplaceable manufacturing technology in many cases. The proof that this branch develops is the still and still bigger quantity of manufactured machines and the permanently increasing number and diversity of actual applications in the manufacture.

The development of high speed machining (High Speed Cutting) was motivated by shortening of manufacturing time and by searching of savings in the manufacturing process, for example by elimination of grinding operations. Moreover, the need increases to machine the materials which cannot be machined by the standard chip technologies. The development is far from its end, nevertheless, the benefits of high speed cutting have been obvious already a few years, in the field of the technology itself (not only the shortened manufacturing time) as well as in the reached accuracies of dimensions and surface quality of workpieces, but also in the total economy of production and in so highlighted environment friendliness.

Characteristics of HPC technology

High cutting speeds – high speed cutting (HSC or also HSM) is not the only technology leading to the acceleration of machining time, etc., so it has all positives and benefits which are mentioned in the section text. In addition to this technology using the high cutting speeds, there are the so called hard machining (Hard Milling) and the high removal machining by means of high feeds (HFC or HFM) available which find their utilization especially at milling operations (Fig. 5.5.1), The mentioned technologies have the common feature that they help to machine quicker, more precisely or they help to machine the materials which are hard machinable. Nevertheless the mentioned technological approaches are not identical, as it is proven by Fig. 5.5.2. The aspect common for them is the technical and economical aspect and therefore we speak about machining using the higher (high) technological parameters (High Performance Cutting). The difference in the used terminology consists in the fact, whether we speak generally about chip machining (C as cutting) or whether we concretize the application of the given approach to the particular technology (M as milling). Of course, the first letters of other technologies can also appear in the name. As as example it is possible to mention high speed grinding which is also developed and improved. The text of this section is aimed at the mentioned chip technologies to the extent adequate to the main topic – i. e. to

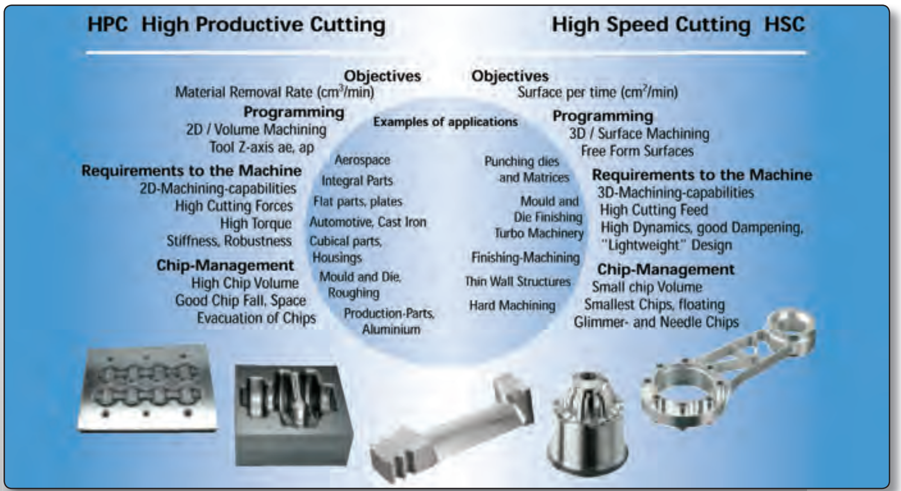

Fig. 5.5.2: Comparison of two main technological trends at High Performance Cutting [Mikron]

High speed – high tool cutting edge speed towards the workpiece*	Hard – machining of materials which are machined with difficulties**	Dry – machining without utilization of cutting liquids***	High feeds – standard cutting speeds and big material removals

Machined material → **Machining at increased technological parameters (HPC)** ← Manufacturing technology

Machine	Technology	Other
Mechanical building: • big dynamics of drives • higher working feeds • dynamic rigidity of frames • spindle run accuracy • high spindle speed • cooling of spindles and drives Control: • filtres and offsets, correction routines for high quality contours and surface (curve) smoothness • quick processing of data and data blocks • optimization control tools related to the mechanical machine part	CAM: • specific NC code ctreation • specific milling strategies (tool trajectory …) Tool: • sharpness and durability of the cutting edge • cutting edge geometry • tool shape • tool material • static and dynamic equilibration of the tool and of the clamp • tool inclination towards the workpiece (it is related to programming and to the machine)	• machine foundation, setting and levelling • cooling (by coolant, MQL, cryogenic) • chip removal • air exhaustion and filtration • protective guards (tightness, minimum noise) • tool adjustment • new technological processes • technology adaptation for the particular workpiece • manufacturing reorganisation (limitation of grinding)

** the simplified definition, it is completed by mechanics of chip creation and formation, changes of mechanical properties and other things*
*** it expresses the relative possibility to machine hardened heat treated steel and hard machinable materials by chip machining*
**** it does not mean that some tool cooling technology is not used*

Fig. 5.5.1: Machining at the increased technological parameters – High Performance Cutting

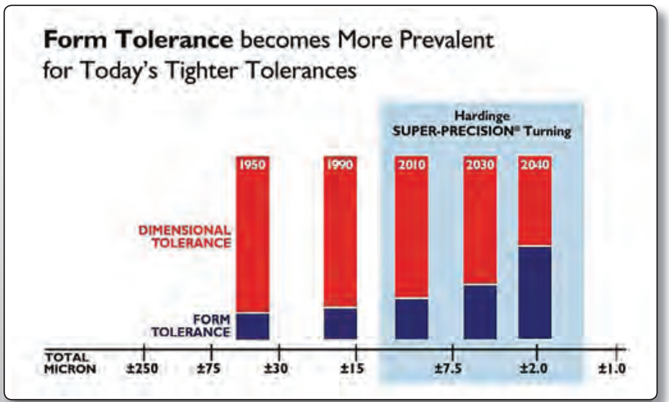

Fig. 5.5.3: Development of the expected machining precision increase [Hardinge]

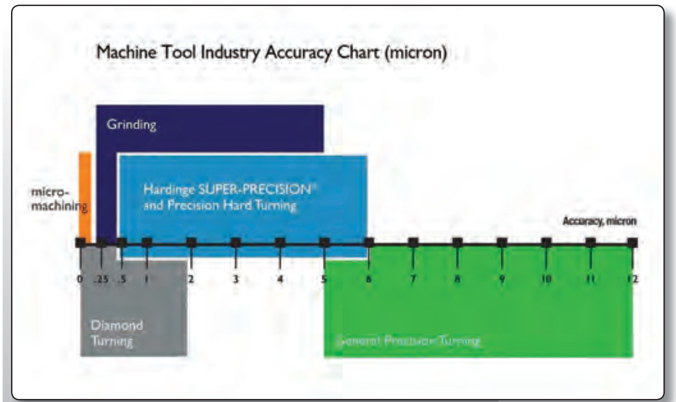

Fig. 5.5.4: HSC technologies replace grinding [Hardinge]

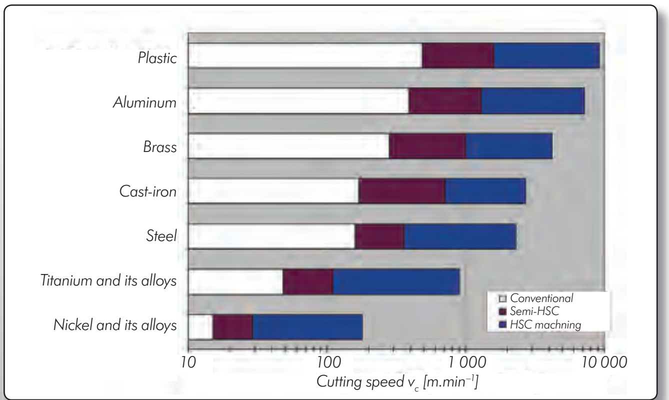

Fig. 5.5.5: Speed ranges of HSC technologies according to Walter company [Walter]

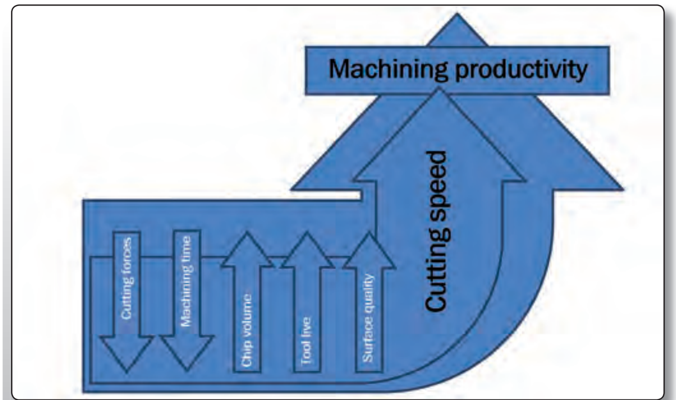

Fig. 5.5.6: Benefits of the cutting speed increase

the machines which are able to create the necessary operational parameters for these technologies (i. e. especially speed and feeds). Fig. 5.5.3 and Fig. 5.5.4 illustrate the development of the branch of machine tools and chip technologies with increased technological parameters.

Note: In the practice as well as in the academic groups it is possible to meet the abbreviation HPM (High Performance Manufacturing). However, the chip machining technology is not hidden behind this term in this case. This is the name of the whole enterprise strategy which includes management, human sources, manufacture and logistics.

When the machine tools are supplied with the spindle speed of e. g. 10 000 min^{-1}, it does not still mean that these machines are determined for high speed cutting. So that it can be possible to speak about high performance cutting, the cutting speed must be reached which leads to the changes of the mechanical material properties and to the chip creation connected with it. However, the chips are different for various machined materials as well as for various technological operations. DMG/Mori company uses the definition that it can be spoken about HSC when the cutting speed is five times and ten times higher compared with the conventional strategy (usual cutting speeds). Moreover, Walter company has

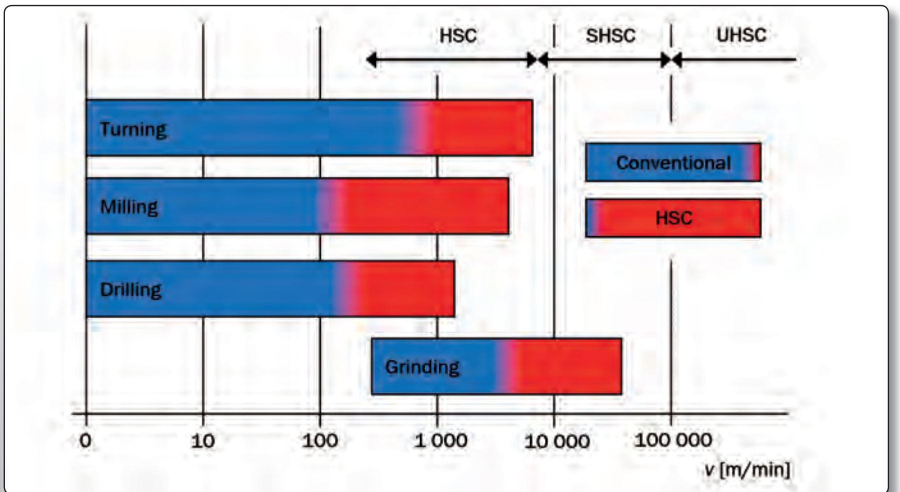

Fig. 5.5.7: Manufacturing technologies and used cutting speeds

considerably the more precisely determined branches of conventional machining and high speed cutting (Fig. 5.5.5). When the history of the chip machining technology (which means also HSC) is studied, it is possible to watch the continual movement to higher cutting speeds. So, it is valid also at HSC that the current technical parameters of this technology measured with the future development are not constant – the content of the HSC term is relative and it will be relative (Fig. 5.5.7). There are no doubts that the chip machining technologies will be further developed in the near future.

According to the research performed by the institute of machining technology and machine tools at Technische Hochschule Darmstadt, the following phenomena are the main characteristic features of the high speed cutting:

- steel v = 800–1 000 $m.min^{-1}$;
- cast iron v = 850–1 500 $m.min^{-1}$;
- plastic materials stiffened with fibres v = 3 000–8 000 $m.min^{-1}$;
- aluminium alloys v = 3 000–7 000 $m.min^{-1}$;
- bronze, brass v = 1 000–3 000 $m.min^{-1}$;
- titanium high alloys v = 150–1 000 $m.min^{-1}$;
- nickel base alloys v = 60–250 $m.min^{-1}$;
- drilling of plastic materials stiffened with fibres and of non ferrous metals v = 100–300 $m.min^{-1}$.

As it was already mentioned, it is purposeless to determine the exact speed limits. The cutting speed sizes at HSC do not depend only on the kind of the machined material, but also on the kind of technological operations. This relation is shown in Fig. 5.5.6. The reason why it is impossible to determine the exact limits can be seen in the variety of machined materials (various mechanical properties, thermal conductivity, etc.). Moreover, the particular conditions under which the particular material is machined in the practice influence the type of utilized tools, of the machines having various rigidity and dynamics and other things.

The high speed cutting principle is formulated in the simplified way so that at the higher cutting speeds the temperature increases quickly in the place where the chip is cut from the semi product. The quick heating to the high temperature causes the significant change of mechanical properties of the removed material (the material softens even it is melted). The inclination of the sliding plane is changed (the inclination of the primary plastic deformation zone is changed) and the contact surfaces between the tool and the chip are reduced at the same time. The share of the friction is reduced which occurs between the chip and the tool and which influences the heat generation and the heat transfer to the tool is decreased. The intensive (jump) change of the mechanical properties due to the temperature change has the influence on the decrease of the cutting force. The theories mention that the cutting forces do not decrease with the increasing cutting speed at high speed cutting, but they again increase to the conventional value at a certain cutting speed value [Skopeček 2004]. It means that every material has a certain value of the optimum cutting speed, considering the necessary cutting force. The high speed cutting is accompanied by the typical optical effect which can be usually watched (Fig. 5.5.11), because very hot chips go away from the cutting place at the high speed cutting. Especially the machined surface is heated only slightly.

According to the research performed by the institute of machining technology and machine tools at Technische Hochschule Darmstadt, the following phenomena are the main characteristic features of the high speed cutting:

- the volume of the removed material increases three times up to five times;
- the feed speeds increase five times up to ten times;
- the cutting forces decrease by 30 %, because the chips are less squeezed, i. e. the passive force deforming the workpiece decreases considerably so it is possible to manufacture thin walled parts;
- the heat tool stress is reduced considerably, because almost all heat is removed by the chips and it does not pass to the tool. This is especially favourable for the machined materials which could be damaged or deformed by the increasing heat;
- the high surface quality is reached at the high speed cutting;
- the reduced stress of the tool and of the machine by the cutting force results in the higher long term machining accuracy;
- machining with high speed means the very high excitation tool frequency, so it is very probable that machining is performed out of the zone of the critical frequencies of the assemblage "machine – tool – workpiece";
- it is also possible to use simpler clamping devices, because the forces which it is necessary to be resistant to are lower than at the utilization of classical technology.

The reduction of the main machining times can be reached by the increased material

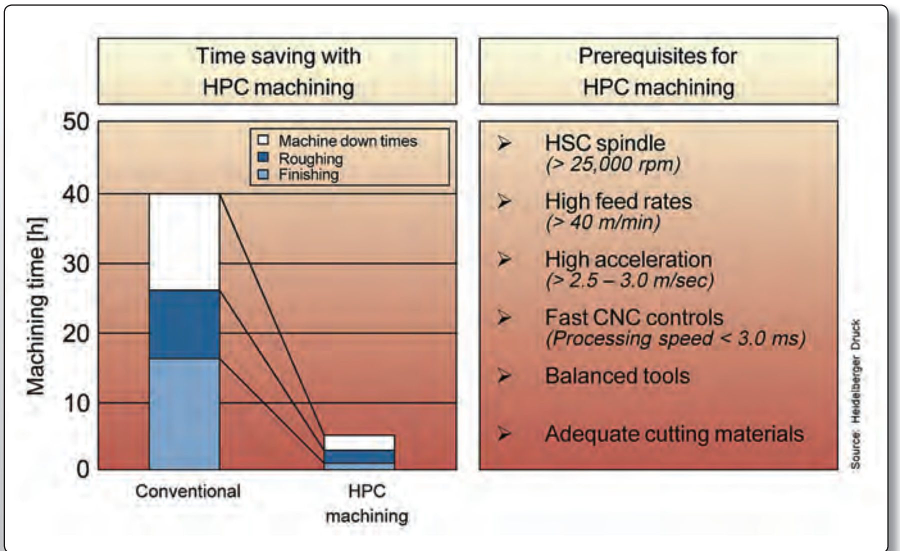

Fig. 5.5.8: Example how to increase productivity using HPC [Ceratizit]