When precision and surface quality are paramount

Surface quality: gloss milling or polishing?

Gloss comparison between a workpiece milled with a conventional approach (left) and a comparative part machined with modern tools and strategies (Photos: MMC Hartmetall)

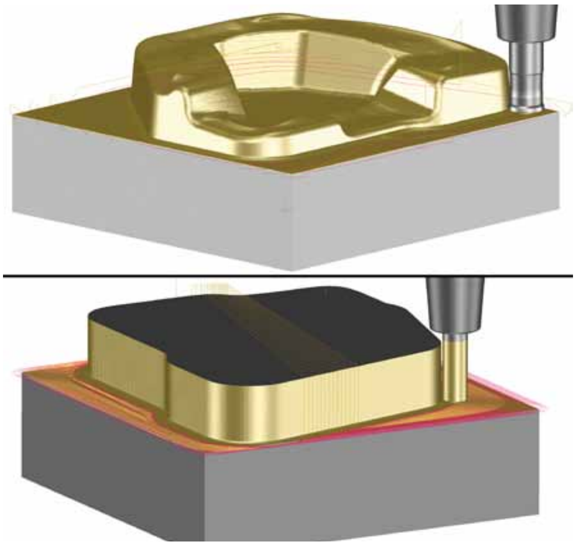
If the highest surface quality is required during milling, additional polishing is usually carried out after finishing. For typical tasks in mould making, the required time can range from a few hours to several days. Nowadays, however, it is becoming increasingly difficult to find skilled workers for such tasks. Furthermore, many customers forbid polishing because it results in a loss of geometric accuracy. In addition, there are aspects such as automatability and control of quality. This favours approaches producing the highest attainable surface qualities directly through milling. However, the question often arises as to whether the additional cost of producing high-gloss surfaces by machine is economically justifiable. For example, there are wide areas in which a good surface can be achieved quite easily with good economic efficiency. At a seminar in Attendorn, the machine manufacturer Röders, the tool manufacturer Mitsubishi Materials and the CAM software developer Tebis compared these two approaches in terms of costs and economic efficiency. It was also shown how optimum geometric accuracy and surface quality can be achieved by combining milling centre, tools and CAM software.

The tests were carried out by machining two identical inserts for a sheet metal forming tool starting from blocks of cold work steel with 48 HRC. Both specimens were milled in a 5-axis Röders RXP601DSH milling centre, each with its specific CAM strategies and matching set of milling tools. For the first workpiece, tools and milling strategies corresponded to procedures traditionally applied in mould making using 3-axis milling strategies. This approach will be referred to as "classic" in the following. By contrast, for the second piece, the possibilities of efficient 5-axis CAM strategies using 5-axis HSC milling and related tool designs were fully exploited. It must be conceded however that this "modern" approach requires considerably higher programming expenditure, especially for finishing. In both cases, the goal was to achieve an optimal result in terms of geometric fidelity and surface quality.

CLASSIC MILLING STRATEGIES

"Milling strategies that have established themselves from the age of 3-axis milling centres often dominate in toolmaking," says Marc Fuest, Head of Partner Support at CAD/CAM software developer Tebis AG in Martinsried. The reason for this approach is that many departments lack the time to search for new tools as well as strategies. In traditional roughing, the material is usually removed plane by plane using high-feed tools. Due to time constraints, it is rarely attempted to subdivide the part contours into flat or steep areas, although milling flat areas with solid carbide cutters and an adaptive milling

Organiser: Moderator Ferdinand Hoischen (Tebis, Cooperation Manager), Marc Fuest (Tebis, Head of Partner Support), Jörg Janke, (MMC Hartmetall, Technical Trainer) and Dr Oliver Gossel (Röders, Head of Sales) (from left to right, Photo: Klaus Vollrath)



Roughing strategies: Top: contour-parallel, using a high feed tool, bottom: adaptive, using a solid carbide tool (Graphic: Tebis)

strategy would be more effective. For the same reason, i.e. trying to reduce programming work, combinations of 3-axis and 5-axis strategies are often avoided. The advantage of this approach is that the required NC programmes can be created easily and quickly, which has a positive effect on the expenditure related to CAM-programming.

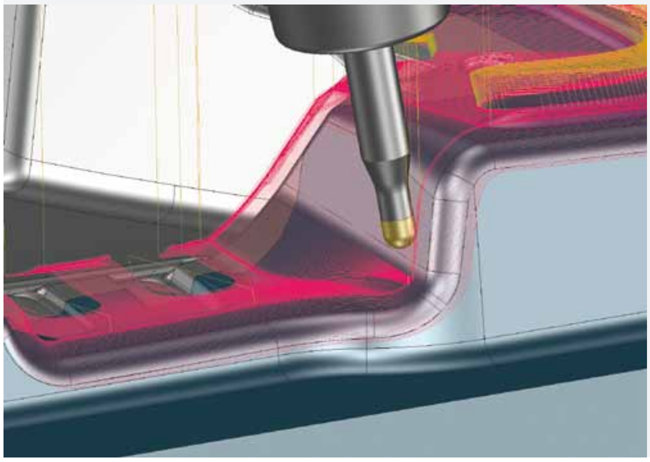
INDEXABLE INSERTS HINDER AUTOMATION

“In the classic approach, users often prefer to remove the bulk of the material using high-feed milling cutters,” explained Jörg Janke, Technical Trainer at MMC Hartmetall, the European headquarters of Mitsubishi Materials. Therefore, an end mill with indexable inserts was used for this purpose. The decisive disadvantage of such a milling cutter solution is that it prohibits unmanned operation and thus full automation. The reason for this is the risk of serious damage if a cutting insert breaks. Compared with indexable insert tools, the process-reliable tool life of solid carbide cutters is considerably longer, so that unmanned roughing is also possible.

FINISHING AND SURFACE QUALITY

“Unfortunately, surface quality is also seldom in the foreground when it comes to finishing strategies,” explains M. Fuest. Users often opt for milling cutters that are too large, which leaves more residual material, which has to be expensively removed in subsequent work steps. Although, for example, there are only nuances between the lateral infeed of a D16 ball cutter compared to a D12 ball cutter, significantly more time must be spent subsequently when machining the residual material areas than could previously be saved by the larger infeed. In practice, a component is often first machined with a 3-axis Z-constant feed and then with a 3-axis axis-parallel feed in order to minimise this residual material. Although this is easy and quick to program, it costs considerably more in machining time. Also because of the required programming effort, five-axis collision avoidance options are switched on too rarely.

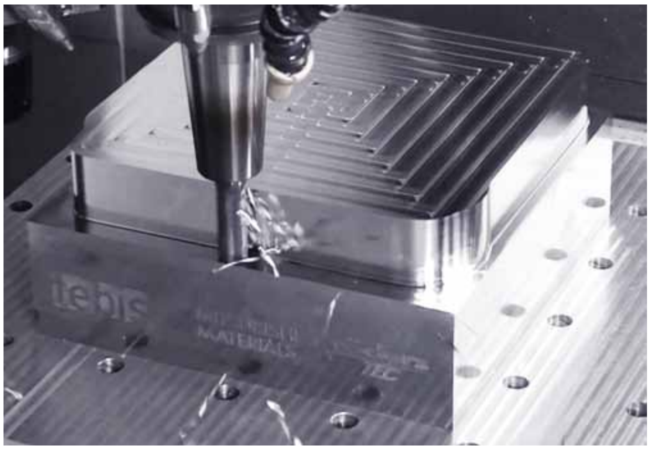
If better surface qualities are to be achieved, especially high-gloss surfaces without manual reworking, 5-axis milling is indispensable. The milling path must follow the surface and the tool must always engage at an angle of inclination to avoid a centre cut.



Modern finishing: 5-axis synchronous with path distances depending on curvature detection (Graphic: Tebis)

HIGH-PERFORMANCE TOOLS FOR EFFICIENT MACHINING

“As an alternative to the high feed cutter, a solid carbide torus cutter with long cutting edges is recommended for roughing”, states J. Janke. In the “modern” approach, therefore, a DIAEDGE brand milling cutter from Mitsubishi Materials’ MP series with a diameter of 12 mm and a corner radius of 1 mm was used. The video sequence of the use of this tool was received with great interest by the participants. It is suitable for trochoidal milling with high material removal via the long lateral cutting edges. Even with classic use, the metal removal rate of this milling cutter therefore exceeds that of a high-feed cutter. A coated solid



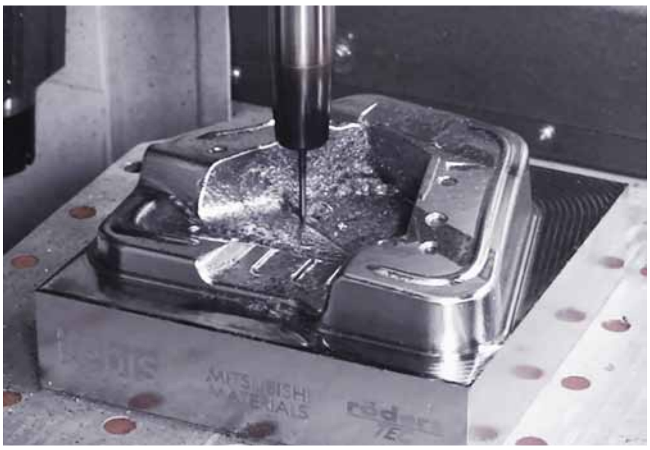
Roughing modern: Trochoidal solid carbide roughing cutter with corner radius MPMHVRBD (Image: Röders/MMC/Tebis)

Modern finishing: VHM barrel cutter VQT6URR with 6 cutting edges for highly productive finishing with large infeed (Image: Röders/MMC/Tebis) carbide barrel cutter with a 10 mm shaft and 6 teeth with a radius of 85 mm was used for the highly productive finishing of flanks. The large radius enables high-depth infeeds on the workpiece flanks with 5-axis adjustment. For narrow areas, for example, a high-precision 1 mm solid carbide ball cutter with two polished cutting edges is suitable for machining narrow fillets and transitions with very good results. Basically, of course, good results can only be achieved with good machine tools.

REQUIRED: A MILLING CENTRE THAT IS BOTH ROBUST AND PRECISE

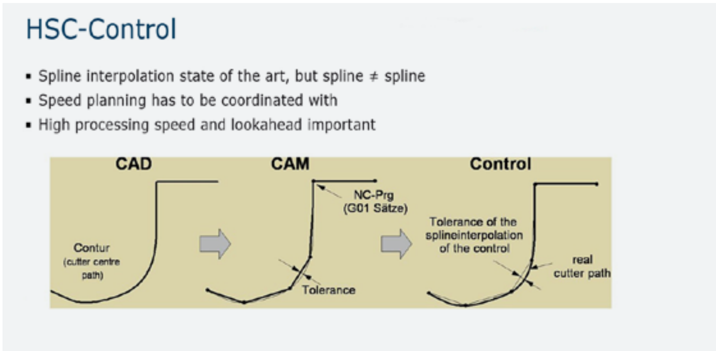
"Important for high economic efficiency is the execution of all operations in the same clamping in the same machine," says Dr.-Ing. Oliver Gossel, Head of Sales at Röders GmbH in Soltau. To achieve this, the machine must in particular be able to achieve the required accuracy and surface quality in addition to the necessary roughing performance. The 5-axis Röders RXP 601 DSH used for the tests is extremely robustly built to be able to rough as well as finish. The HSC spindle reaches up to 30,000 RPM. The portal design and the rotary axes with heavy-duty counter bearings ensure maximum rigidity. For optimum accuracy, frictionless direct drives are used in all axes, supported in the Z-axis by frictionless weight compensation. Another special feature of the machine plays a role especially in the changes of direction that are so important for precision machining: thanks to the particularly high "jerk" (change in acceleration per time) of the drives, the intended feed rate can be maintained for as

Semi-finishing and classic finishing: solid carbide ball nose end mill MP3XBR with conical neck for semi-finishing and finishing of deep cavities. (Image: Röders/MMC/Tebis)



Classic and modern finishing: 1 mm ball nose end mills VFR2SBFR with highly polished cutting edges. (Image: Röders/MMC/Tebis)

The RXP 601 DSH 5-axis milling centre from Röders used for the machining tests (Photo: Klaus Vollrath)

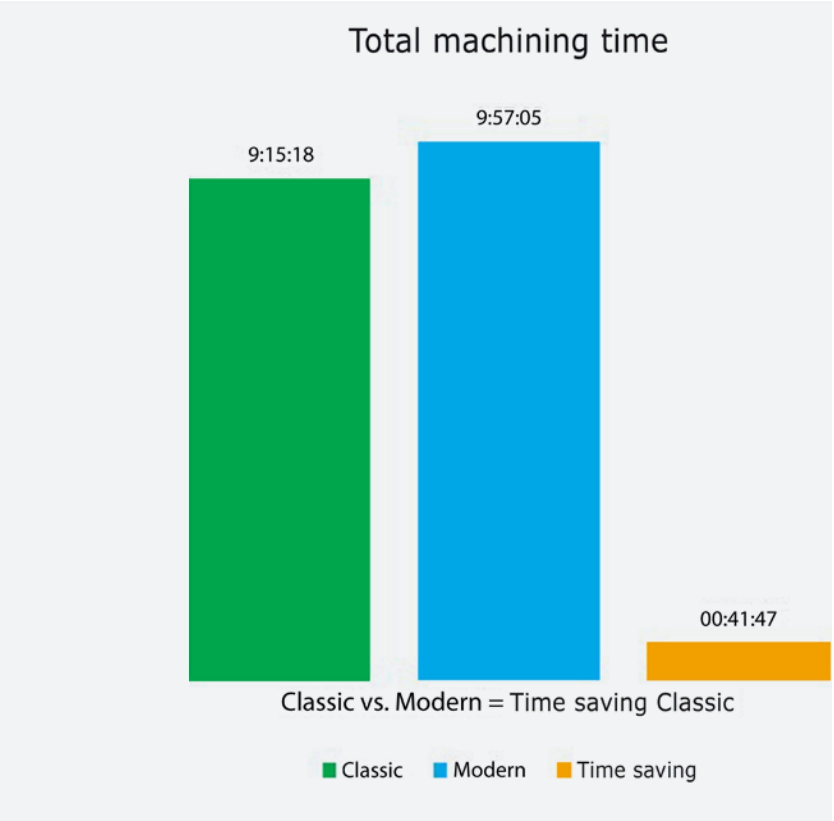


Thanks to high control speed and internal spline interpolation, the Röders control achieves a high surface quality with minimum machining time (Graphic: Röders)

long as possible even in highly curved surfaces. Sophisticated temperature management plays a special role: since heat is the enemy of precision, all major components of the system have their own temperature control. The temperature of the temperature-control medium circulating through all relevant machine components is kept stable with an accuracy of +/- 0.1 K. The outstanding unique selling point of the Röders systems is their proprietary control system. With a block processing time of less than 0.1 ms and a look-ahead of more than 10,000 blocks, optimum accuracy and surface quality are achieved. Particularly noteworthy is the exceptionally high control speed with a cycle of 32 kHz in all axes. This corrects the tool path every 0.03 ms.

DISCUSSION: GLOSS MILLING OR POLISHING

A comparison of the two strategies showed that the programming time of 0:27:30 for the "classical" strategy was only one tenth of that of the "modern" variant with 4:40:15. In the total processing time, on the other hand, the difference was only about 42 minutes in favour of the "classical" variant. Thus, this approach has clear advantages from this point of view. However, according to the estimates of the experts attending the lecture, it can be assumed that the time required for polishing this component is probably of the same order of magnitude as the additional programming required for "milling" the equivalent surface on the "modern" milled workpiece. The proportionate "real" tool costs added up to € 524 and € 426 respectively. However, if customer requirements stipulate that an optimal surface quality has to be achieved directly by machining, i. e. without geometry distortions due to



Balancing the machine processing time resulted in a time gain of approx. 42 min for the "classic" approach (Graphic: Tebis)

During the concluding discussion, some of the practitioners present estimated that longer programming times with the "modern" milling strategy would at least be offset by savings in polishing expenditure (Photo: Klaus Vollrath)

manual reworking, the time required is not the main factor. The "modern" milled variant achieved a roughness Ra of 0.238 µm, compared to 0.617 µm with the "classic" procedure. In the course of the presentations and discussions, it became clear that more and more customers are placing high and the very highest demands on surface quality in mould making. Often, any polishing is prohibited, as this jeopardizes the geometric accuracy and the level of process control. The participants reported polishing times for tools of comparable complexity to the presented application of up to 35 hours. It was repeatedly said that better surface quality and the possibility of running automatically in the "ghost shift" also justify higher expenditure on programming and machine running time. On the other hand, there are still many applications where the classic approach achieves an economically optimal result, as both programming and machining expenditure are lower.

The conclusion was that very good results can be achieved with both strategies. The user should therefore choose his approach according to his requirements.
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