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Achieving mirror surface finishes by milling

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In years gone by, achieving a good surface finish simply required the use of grinding machines and a detailed knowledge of the best grinding wheel for the application. Today, the options available to engineering companies are wide and varied as there are many different types of machines on the market.

This article focuses on the requirements needed to achieve mirror surface finishes by milling. If one has access to physical surface comparison milling and grinding charts, it can be seen that Ra 0.4 μm (16 μm centre line average (CLA)) and Ra 0.025 μm (1 μm CLA) are generally regarded as the best achievable finishes for milling and grinding, respectively. It is, in fact, possible to achieve less than Ra 0.013 μm finishes by milling, but a great deal of care, consideration and discipline are required.

Invariably, the workshop temperature plays a major part in what can be achieved, and it is here where the whole system can fail before the project is started. Tying the temperature variation down to 1°C gives the machine tool a fighting chance of not growing or shrinking during machining. This consistency of temperature is critical, taking into account the effect temperature has on machine tools; even machines that have granite beds and are known to be very stable can move if the temperature in the room varies.

Temperature is so important that the machines capable of high accuracy or really high surface finishes have coolant channels in the castings to keep the temperature constant. The need to cool when spindle speeds are high and keep warm when they are low is critical for consistency. Depending

on the workpiece and cutting tool, it is common to see spindle speeds in excess of 40,000 rpm being used. In addition, depending on the application, some machine manufacturers offer standard spindles with up to 80,000 rpm and tool change.

A key component in machining centres is the spindle. It is obviously essential to know the speed that the spindle can achieve and if the tool exhibits any spindle run-out, but equally important is being aware of the age of the tool holder or collet. The tool holder should be the best available in order to achieve the best results.



► The Kern Micro HD CNC machining centre for high-precision prototype and serial production. ►

It is worth performing checks to ensure that the machine has not had any problems that could hinder achieving the highest accuracy or surface finish, for example, making sure that the spindle is perpendicular to the movement of the table and that some maintenance has been performed on the machine if the operator has had a crash.

Historically, the best surface finishes have been achieved on grinding machines that have hydrostatic guideways. However, in recent years, excellent results have also been obtained on machining centres, since their transmission of movement to an axis has improved significantly. Today's machining centres can include linear drive systems to each axis or hydrostatic ballscrews so that there is no metal-to-metal contact in the ballscrew and nut but rather a film of oil between the

thread of the ballscrew and the thread of the nut. Both examples transmit the movement of the axis, but it is the hydrostatic ballscrews that ensure smooth movement.

There are also a number of key considerations in the cutting area of a machining centre, relating to lubrication, the workholding, the cutting tool itself and parameters such as tool measurement tolerances and depth of cut (DOC).

Thought needs to be given to whether a workpiece material is best cut dry or with a coolant or lubricant. A lubricant cannot be too thick for high surface finishes, rather it should be very thin and not sticky, so that it aids temperature reduction of the cutting tool as well as lubricates.



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► An aluminium mirror surfaced disco ball, produced on the Kern Micro HD CNC machining centre. ►



► An aluminium mirror surfaced model of the Cloud Gate, otherwise known as 'the Bean', in Chicago, US, by Indian-born British sculptor Sir Anish Kapoor, produced on the Kern Micro HD CNC machining centre. ►



The workpiece needs to be held rigidly to achieve a high surface finish, but as softer materials are becoming more popular, greater care must be taken as to how these are held. There are limited options for vices and three-jaw chucks, and in many instances, workpieces are held from the back. This means they are not subjected to compressive or side forces and do not exhibit deformed surfaces when released.

The cutting tool needs to be the correct type of tool, namely ball nose or corner radius end mill, made of the correct material and ideally suited for machining the workpiece material. It also needs the stability of form to machine the surface requested so that it does not deform and create other issues. Diamond and cubic boron nitride (CBN) tools are commonly suggested because they have sharp edges and are long-lived, but due consideration should still be given to tungsten carbide, remembering that one should select the best cutting tool material for the workpiece material.

It should also be remembered that not all end mills are the same, for example, they may have the same number of teeth but not match in terms of accuracy of tolerance and form. Some tool suppliers offer tool measurement certificates that state the radius (ball nose or corner) is within a certain tolerance, normally ± 0.003 mm. These certificates also show the positioning of deviations and if they are likely to affect the component.

If all of the aforementioned criteria have been satisfied, the final point to consider is depth of cut (DOC). To achieve the best mirror surface finish, the cutting tool must not be overworked or this is going to affect the cutting edge fairly quickly. It is advisable to look at a DOC of no more than 5 μ m, then the stepover also needs to be in that magnitude relative to the tool diameter to ensure that the side forces are not overly strong.

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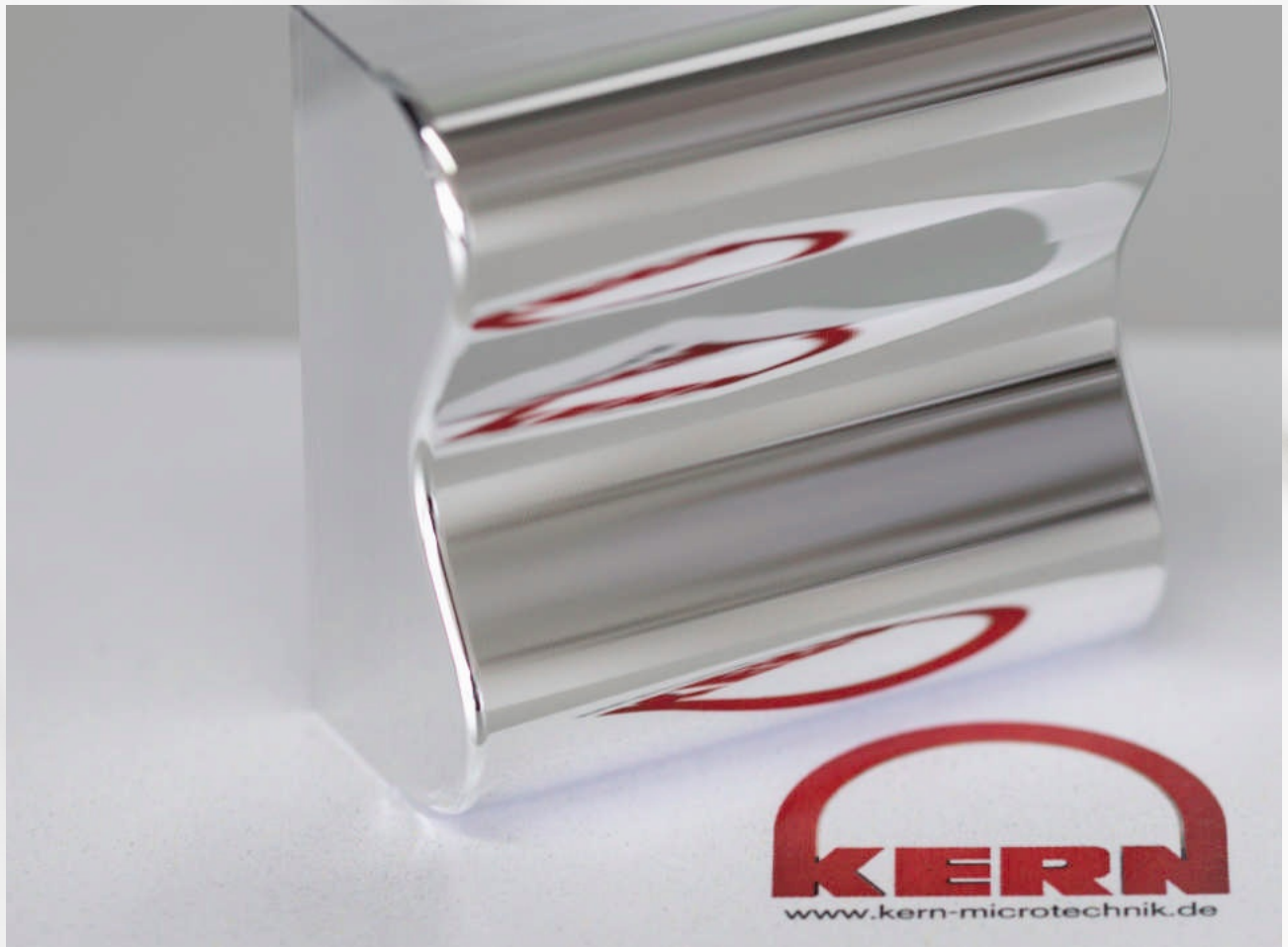
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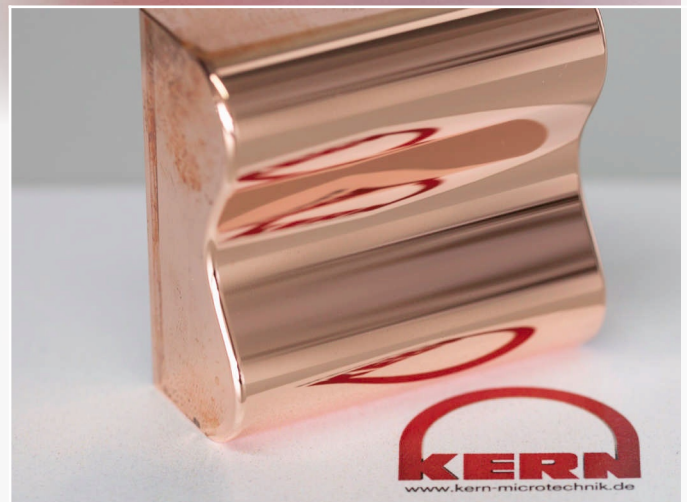
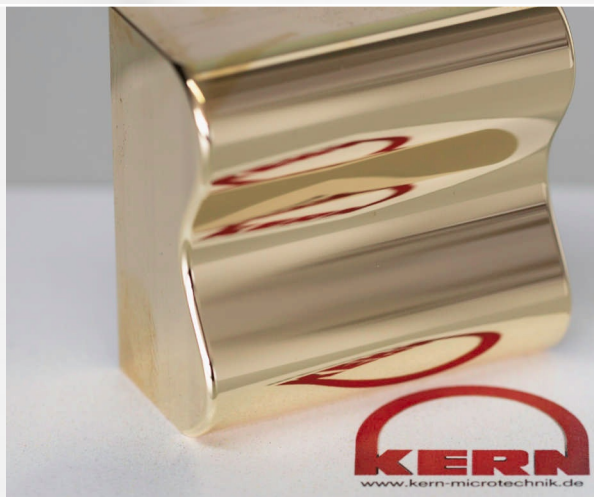
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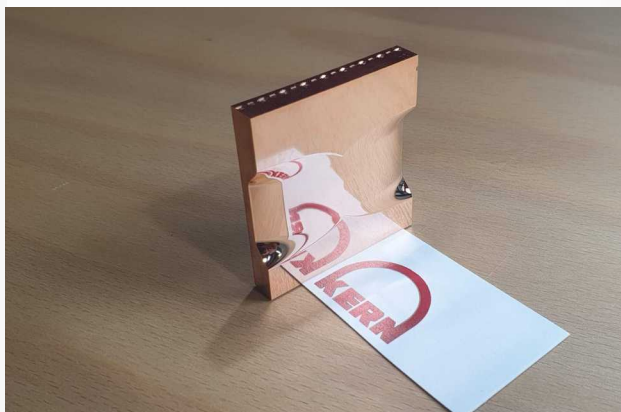
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► Wavy mirror surfaces in aluminium (above), copper (right) and brass (below), produced on the Kern Micro HD CNC machining centre. ►





► A flat and wavy mirror surface in copper, produced on the Kern Micro HD CNC machining centre. ►

Mirror surface finishes can be achieved for a number of materials, namely aluminium, brass, copper, gold, nickel and silver and gold as well as various steels. However, it is important that the designer does not choose the wrong material or request a surface finish that is especially difficult to achieve, resulting in the part not being fit for purpose. Furthermore, it is critical that the manufacturer understands what the designer wants to achieve and that the machines and processes to be used are capable of delivering the required results.

The demands of today's manufacturing environment are increasingly complex, but they are being met by companies that give due thought to all of the aspects required to produce mirror surface finishes successfully; and the results are exceptional if one uses as a yardstick those judged to be good just a few years ago. ●

Arthur Turner, specialist in micromachining



The demands of today's manufacturing environment are increasingly complex, but they are being met by companies that give due thought to all of the aspects required to produce mirror surface finishes successfully.



► Wavy mirror surfaces of varying contours in steel, produced on the Kern Micro HD CNC machining centre. ►

