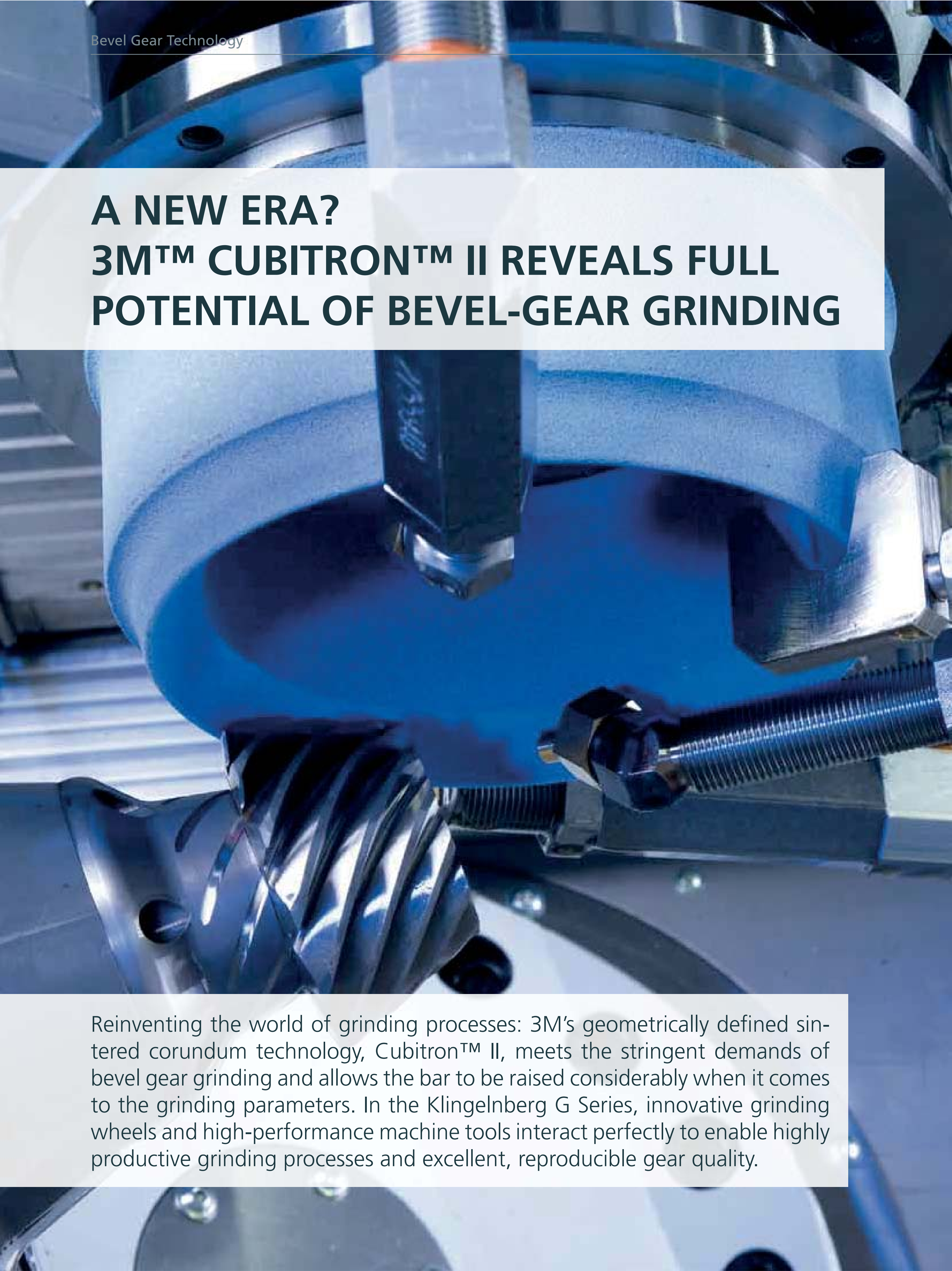


A NEW ERA?
3M™ CUBITRON™ II REVEALS FULL POTENTIAL OF BEVEL-GEAR GRINDING

Reinventing the world of grinding processes: 3M's geometrically defined sintered corundum technology, Cubitron™ II, meets the stringent demands of bevel gear grinding and allows the bar to be raised considerably when it comes to the grinding parameters. In the Klingelnberg G Series, innovative grinding wheels and high-performance machine tools interact perfectly to enable highly productive grinding processes and excellent, reproducible gear quality.

Compact

Increased Productivity with a New Grinding Material

Brand new horizons for gear grinding during bevel gear cutting, thanks to the new Cubitron™ II grinding material, which now makes this production step much more reliable and efficient.

As the last production step in bevel gear cutting, gear grinding has a particularly important role to play. Roughing and finishing often coincide, especially in the automotive industry. In this context, the topography and pitch of case-hardened gear teeth must be achieved with tolerances of just a few micrometers and the required surface finish, without incurring grinding burn. The key issue here is to eliminate hardening distortions, which lead to significant allowance fluctuations within the process. At the same time, the intergranular oxidation layer resulting from the hardening process, which causes loading on the grinding wheel, must be removed. This makes the ground component susceptible to thermal microstructural damage – and as this has a detrimental effect on the component service life, it must be avoided.

Process Development

When it comes to the further development of the bevel gear grinding process, there are two main aims: to increase productivity and to improve process reliability. The latter is an important factor in ensuring that the strict requirements for geometric component accuracy (pitch and topography) are met in a reliable and reproducible manner – without compromising the surface finish of the tooth flank as a functional surface. This produces conflicting aims which cannot be resolved with the sintered corundum grinding material commonly used today. An increase in productivity calls for stricter machining parameters. However, these tend to result in poorer surface characteristics and create a risk of thermal microstructural damage, which must be avoided at all costs.

The special cutting conditions that go hand in hand with the new Cubitron™ II grinding material go some way toward resolving the conflicting aims described above: the thermal load on the component is significantly reduced, thereby lowering the risk of grinding burn. This boosts productivity considerably (Fig. 1). So, as they attempt to create a grinding wheel specifically for machining bevel gears, what should the developers now be aiming for? They need to design the grinding wheel in such a way as to achieve sound roughness values – even in the face of more demanding cutting data – and to minimize macrogeometric wear. This will provide the foundation for reproducibly high component quality.

Low grinding wheel wear minimizes the extent to which the machine must compensate for pitch errors, making the process result less susceptible to component batch fluctuations. As a result, the entire process becomes more reliable. As a secondary effect, the dressing amounts can be reduced to ensure that the grinding wheel enjoys a long service life.

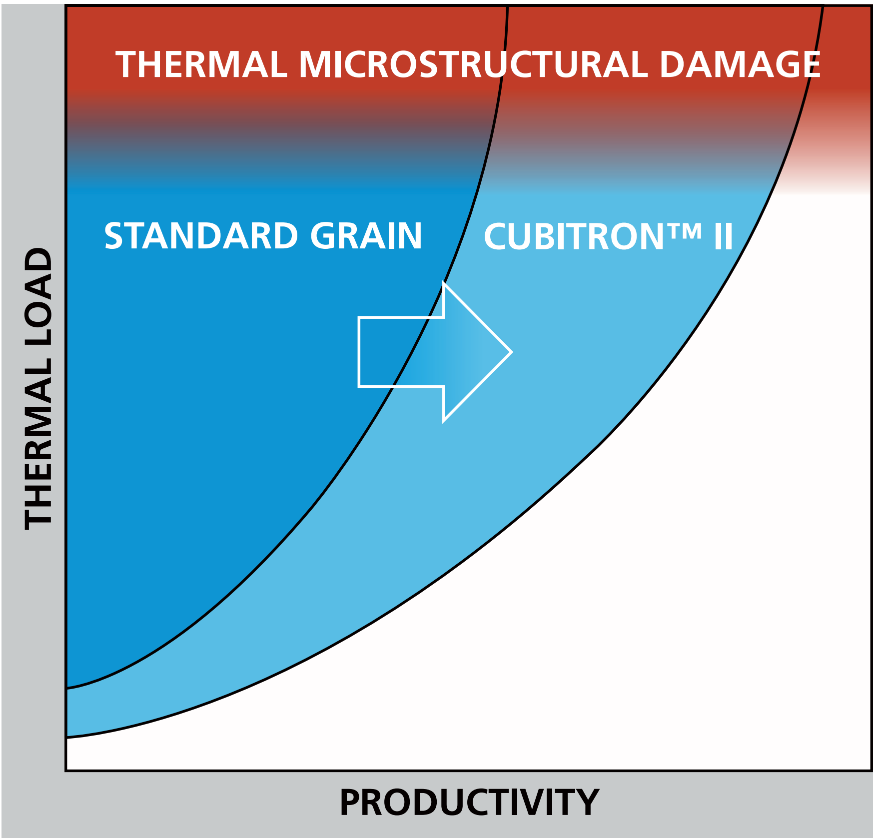


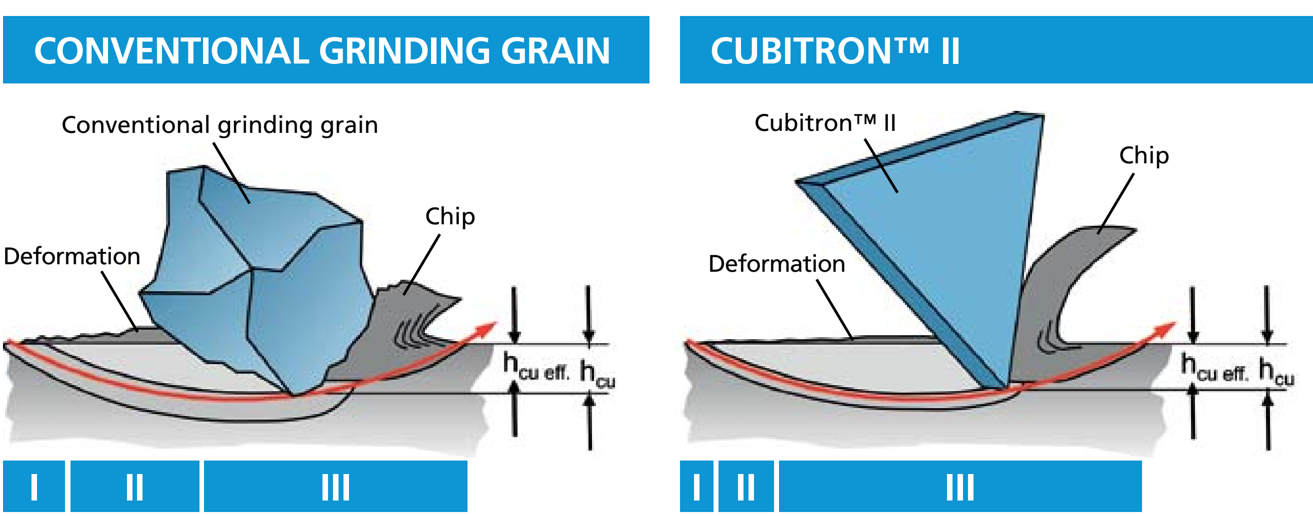
Fig. 1: Thermal load on the component

In collaboration with the Precision Grinding & Finishing Division at 3M, provider of a diverse range of technologies, Klingelnberg presents a new and improved grinding process for producing bevel gears based on the high-performance machines in the G Series and the new grinding material.

Triangles Improve Chip Formation

The individual grinding grains in the aluminum-oxide grinding material typically used for bevel gear grinding today exhibit a random geometry, which – except for a few edges – is nearly spherical. When machining with these grains, the cutting conditions that typically occur are unfavorable and are characterized by extremely negative rake angles. The grains first "plow" through the workpiece, throwing up material (Fig. 2 on left, stages I and II) before chips are formed (stage III). Large amounts of the energy generated in the process are introduced directly into the component as heat due to the elastic and plastic deformation of the material and as a result of friction.

The key advantage of this new grinding process is all down to the triangular granulation of the grinding material: Cubitron™ II consists of precisely shaped triangles of uniform size. These are made from sintered aluminum oxide (sintered corundum) and feature an edge length of approximately 0.4 mm and a thickness of approximately 0.08 mm (Fig. 3). Even when the triangles are randomly arranged in the grinding wheel, relatively favorable cutting conditions prevail thanks to the defined grain shape with its even surfaces and comparatively small wedge angles of 60° and 90° on average. This means we can expect to see more favorable chip formation with less deformation energy (Fig. 2). Deformation in the workpiece material can largely be prevented and the thermal load on the component rim zone can be significantly reduced – in the same way as when machining with a geometrically defined blade. "The defined



Stages of material deformation during chip formation **(acc. to Prof. W. König)**

Significantly reduced material deformation and yielding

Fig. 2: Chip formation, comparative overview

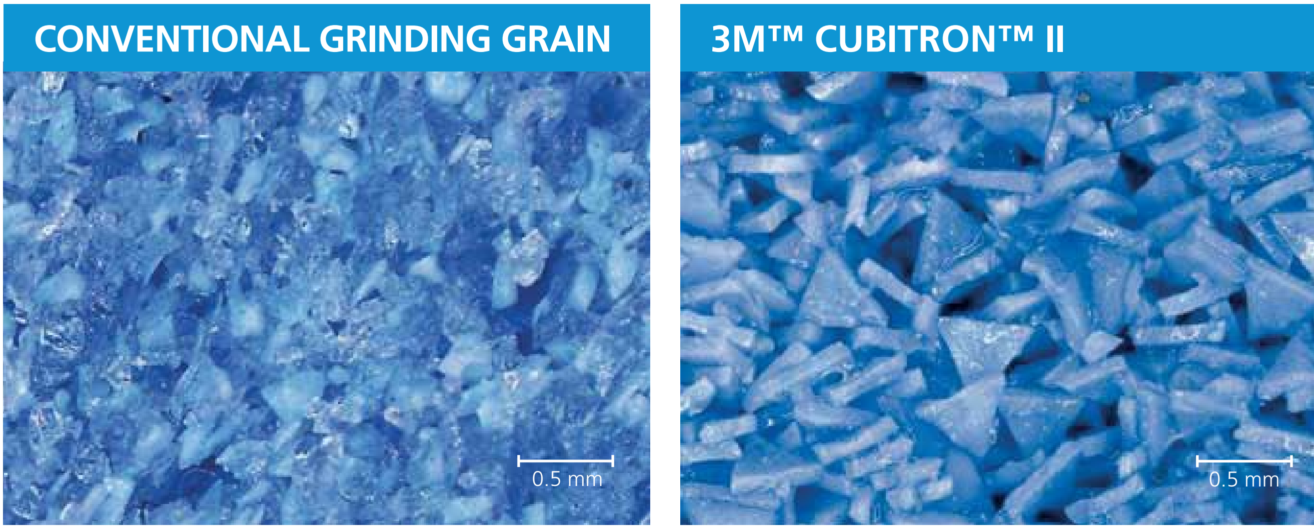


Fig. 3: Grinding wheel microstructure, comparative overview

fracture planes of the triangular grain account for the fact that sharp edges are always present after dressing. Due to the self-sharpening effect, the cutting conditions are not negatively impacted, even in the event of wear on the cutting grain. As a result, the grinding wheel does not become dull," explained Jürgen Hechler, grinding material expert at 3M.

Increase in Productivity – without Grinding Burn

Chip formation with the Cubitron™ II grinding grain is beneficial and helps significantly reduce heat input into the component. This minimizes the risk of thermal microstructural damage to the component rim zone accordingly. A basic test was carried out using the same grinding parameters as for series production when machining automotive ring gears (a process which comes close to causing grinding burn due to the full-surface contact between the grinding wheel and tooth flanks (Fig. 4)). During this test, it even proved possible to do away with the Waguri spindle (eccentric grinding wheel spindle), which is normally responsible for ensuring a minimum level of process cooling – with no resultant grinding burn. When compared with conventional grinding materials, Cubitron™ II is capable of removing as much as double the material during bevel-gear machining – depending on the process – without any grinding burn, without compromising the surface finish.

Reduced Wear

Macrogeometric wear on the grinding wheel can be influenced by the internal structure of the Cubitron™ II grain (grain splitting), the relative pore volume, and the hardness of the vitrified bond.

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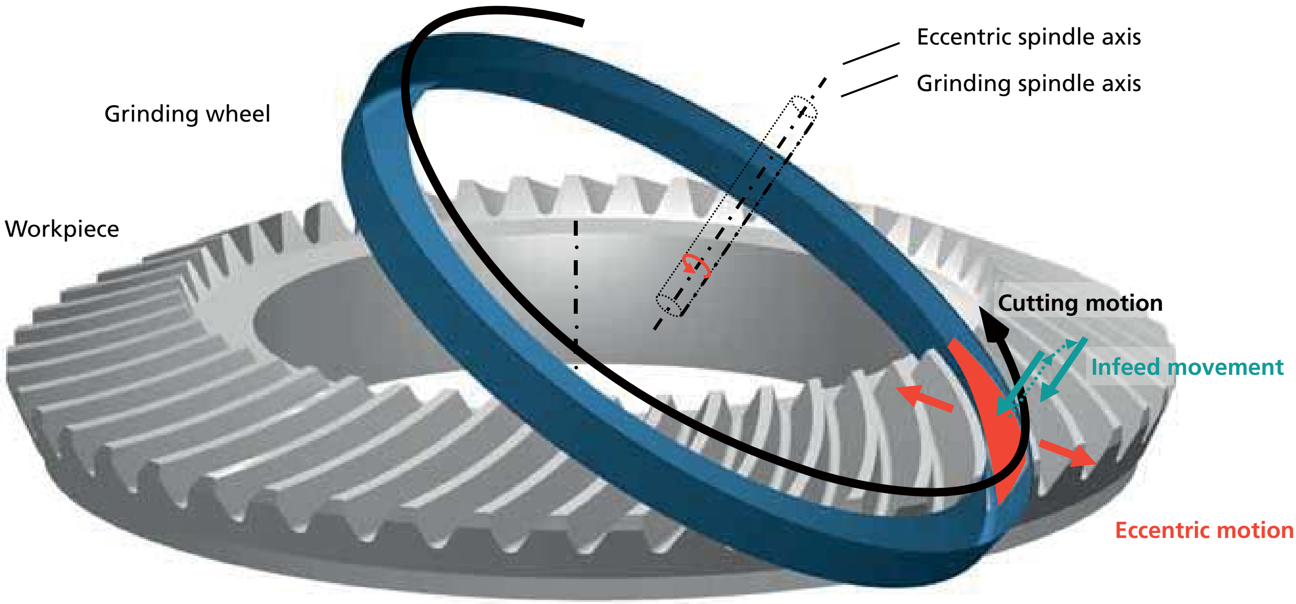


Fig. 4: Immersion-grinding with eccentric motion

The reduction in tool wear of up to 70 % is a major step forward for process reliability, as lower wheel wear compensation values are required.

During the immersion-grinding of ring gears with suitable grinding wheel specifications, tool wear can be reduced by up to 70 % compared with the wear that occurs with a standard sintered corundum grinding wheel. This is a major step forward for process reliability, as the necessary wheel wear compensation values are lower. Consequently, the pitch quality of the gear teeth is significantly less affected by allowance and quality fluctuations from one component to another as well as by the influences of different material batches that affect tool wear – another clear advantage in terms of process reliability. At the same time, the dressing amount can be reduced by up to two thirds. This has positive effects right away, both with regard to the grinding wheel tool life – by tripling it (+ 200 %) – and the load on the diamond dressing roll.

Automotive Industry Benefits

The Cubitron™ II grinding material is suitable for all Klingelnberg bevel gear grinding machines. This grinding material's high levels of productivity and process reliability, coupled with the longer tool life it enables, make it ideal for mass producing gear sets for automobiles and commercial vehicles, for instance. It is an especially attractive and cost-effective option for applications where

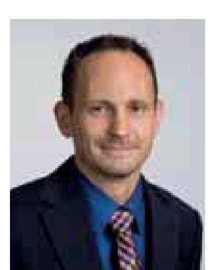
Comparison between various grinding materials and Cubitron™ II

CONVENTIONAL SINTERED CORUNDUM	CBN	3M™ CUBITRON™ II
▪ Sintered aluminum oxide (sintered corundum) ▪ Vitrified bond ▪ Self-sharpening effect due to micro-nicks ▪ Unfavorable chip formation due to extremely negative rake angles ▪ Significant heat introduced into the component ▪ Moderate wear ▪ High degree of flexibility, as grinding wheel can be (re)profiled to a virtually unlimited extent	▪ Cubic crystalline boron nitride ▪ Metal bond (no dressing) or vitrified bond (dressing possible) ▪ Favorable chip formation due to sharper cutting edges ▪ Minimal heat introduced into the component ▪ Extremely low wear ▪ Very little flexibility, as it can only be (re)profiled to a limited extent, or not at all	▪ Precisely formed triangles of sintered corundum with uniform geometry ▪ Vitrified bond ▪ Preferred fracture planes for sharp cutting edges after dressing ▪ Equivalent grain size (fracture behavior) can be adjusted due to grain microstructure ▪ Favorable chip formation due to sharp cutting edges ▪ Minimal heat introduced into the component ▪ Low wear due to favorable chip formation ▪ High degree of flexibility, as grinding wheel can be (re)profiled to a virtually unlimited extent, although restrictions do apply for small outside radii

the number of grinding passes can be reduced without any loss of quality, thanks to the highly stable character of the grinding wheel. The new grinding material will also appeal to anyone who needs to machine large volumes of material within a short space of time.

Grinding Material Taps into New Possibilities

Thanks to the development of this innovative grinding material, the machines in the G Series can come closer to achieving their full potential. Cubitron™ II breaks through the limits imposed by previous grinding materials and is the key to achieving greater cost effectiveness with reproducible high-quality results. In certain respects, the grinding material closes the gap between conventional sintered corundum and CBN (cubic boron nitride): it offers significantly better performance and form stability than sintered corundum, but without the exorbitant tool costs and lack of flexibility in the grinding wheel profile that come as disadvantages in the case of CBN tools. ◆



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